

SUSY, Precision Observables and Collider Implications

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1. Introduction
2. Precision Observables in the MSSM
3. Precision Observables in the CMSSM: collider implications
4. Conclusions

1. Introduction

Q: Which Lagrangian describes the world?

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A: Ummm . . . Let's start differently!

1. Introduction

Supersymmetry (SUSY) : Symmetry between

$$\text{Bosons} \leftrightarrow \text{Fermions}$$

$$Q \mid \text{Fermion} \rangle \rightarrow \mid \text{Boson} \rangle$$

$$Q \mid \text{Boson} \rangle \rightarrow \mid \text{Fermion} \rangle$$

Simplified examples:

$$Q \mid \text{top, } t \rangle \rightarrow \mid \text{scalar top, } \tilde{t} \rangle$$

$$Q \mid \text{gluon, } g \rangle \rightarrow \mid \text{gluino, } \tilde{g} \rangle$$

⇒ each SM multiplet is enlarged to its double size

Unbroken SUSY: All particles in a multiplet have the same mass

Reality: $m_e \neq m_{\tilde{e}}$ ⇒ SUSY is broken . . .

. . . via soft SUSY-breaking terms in the Lagrangian

SUSY particles are made heavy: $M_{\text{SUSY}} = \mathcal{O}(1 \text{ TeV})$

Supersymmetry: Motivation

The SM is in a pretty good shape.

Why MSSM? (Is it worth to double the particle spectrum?)

→ more than 9 reasons as a motivation:
(incl. 3 1/2 exp. verified SUSY predictions!)

1.) (Original motivation:) Stability of Higgs mass against higher order corrections in the MSSM

$$\Rightarrow M_{\text{SUSY}} = \mathcal{O}(1 \text{ TeV})$$

2.) Haag-Lopuszanski-Sohnius theorem:
maximal gauge symmetry for a QFT:
inner gauge symmetry \otimes (local) SUSY

3.) Lorentz algebra \subset SUSY algebra (local)
→ connection to general relativity
Superstring theories contain $N = 1$ SUSY as low energy limit.

4.) Unification of gauge couplings:

Not possible in the SM, but in the **MSSM** (although it was **not** designed for it.)

$$\Rightarrow M_{\text{SUSY}} = \mathcal{O}(1 \text{ TeV})$$

5.) Lifetime of the proton: for SU(5)

GUTs:

$$\tau_{p,\text{SM}} < \tau_{p,\text{exp}} < \tau_{p,\text{SUSY}}$$

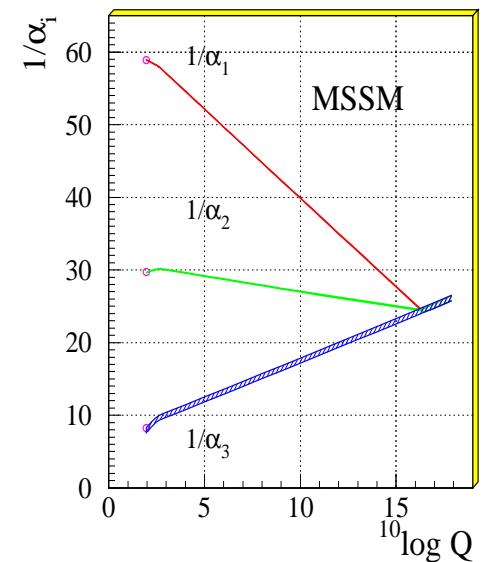
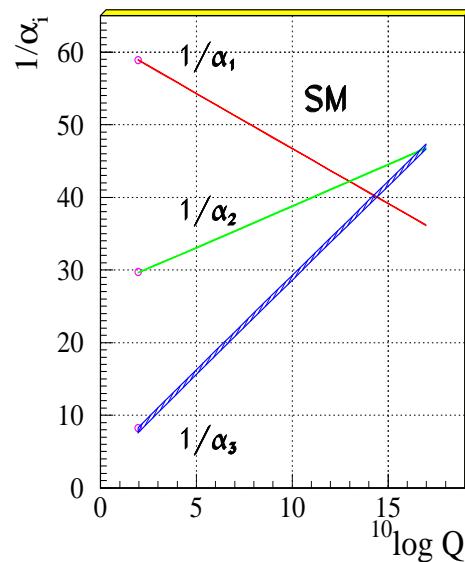
6.) Spontaneous symmetry breaking via Higgs mechanism is automatically achieved in **SUSY GUTs**

$\rightarrow T$

SUSY prediction #1
experimentally verified:

$$m_t = 150 - 200 \text{ GeV}$$

Unification of the Coupling Constants
in the SM and the minimal MSSM



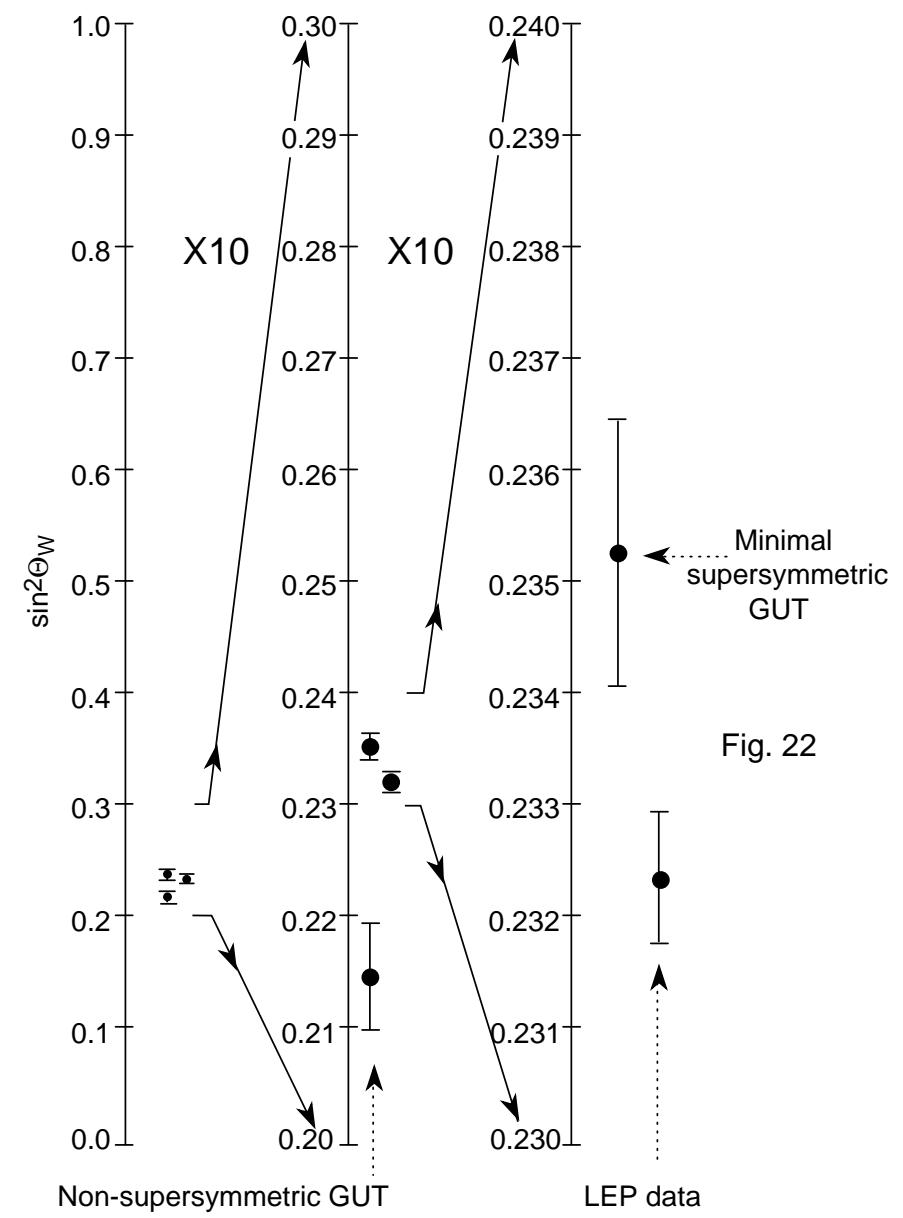
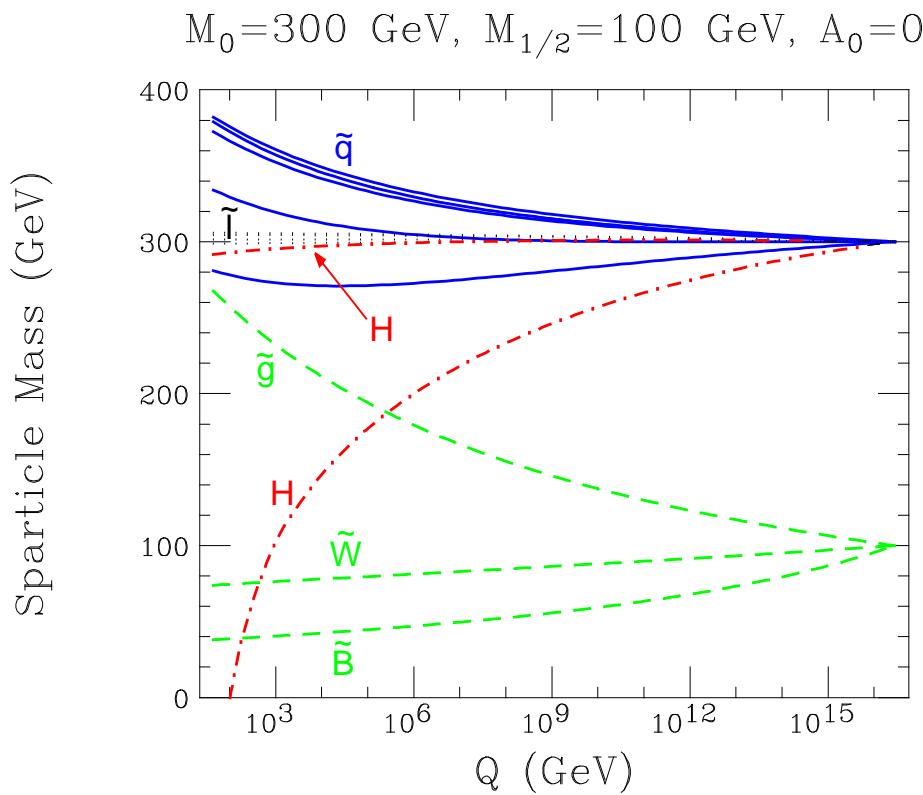


Fig. 22

7.) Prediction for $\sin \theta_W | M_{GUT} = \frac{3}{8}$
low energy prediction via RGE $\rightarrow T$

SUSY prediction #2 exp. verified:

$$\sin^2 \theta_{\text{eff}} \approx 0.232$$

8.) LSP (lightest SUSY particle) is stable

SUSY prediction #3 exp. verified:

cold dark matter

(with correct properties)

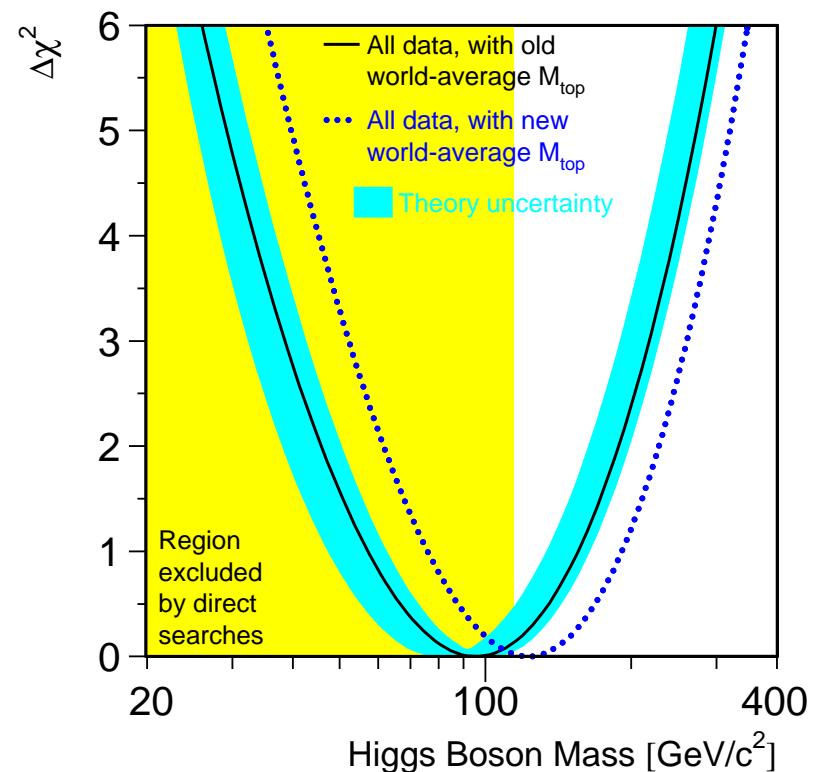
9.) Prediction of a light Higgs boson in the
MSSM (see below): $m_h \lesssim 140 \text{ GeV}$

Indirect search: Global fit to SM data:

[LEPEWWG '04]

SUSY prediction #3 1/2 exp. verified:

$$m_h \lesssim 140 \text{ GeV}$$



...) Solution for Flavor problem? Solution for Baryogenesis?

The Minimal Supersymmetric Standard Model (MSSM)

Superpartners for Standard Model particles

$[u, d, c, s, t, b]_{L,R}$	$[e, \mu, \tau]_{L,R}$	$[\nu_{e,\mu,\tau}]_L$	Spin $\frac{1}{2}$
$[\tilde{u}, \tilde{d}, \tilde{c}, \tilde{s}, \tilde{t}, \tilde{b}]_{L,R}$	$[\tilde{e}, \tilde{\mu}, \tilde{\tau}]_{L,R}$	$[\tilde{\nu}_{e,\mu,\tau}]_L$	Spin 0
g	$\underbrace{W^\pm, H^\pm}_{\text{}}$	$\underbrace{\gamma, Z, H_1^0, H_2^0}_{\text{}}$	Spin 1 / Spin 0
\tilde{g}	$\tilde{\chi}_{1,2}^\pm$	$\tilde{\chi}_{1,2,3,4}^0$	Spin $\frac{1}{2}$

Enlarged Higgs sector: Two Higgs doublets

Problem in the MSSM: many scales

\tilde{t} sector of the MSSM: (scalar partner of the top quark)

Mass matrix for \tilde{t}_L, \tilde{t}_R :

$$(\tilde{t}_L, \tilde{t}_R) \begin{pmatrix} M_{\tilde{t}_L}^2 + m_t^2 + DT_{1t} & m_t X_t \\ m_t X_t & M_{\tilde{t}_R}^2 + m_t^2 + DT_{2t} \end{pmatrix} \begin{pmatrix} \tilde{t}_L \\ \tilde{t}_R \end{pmatrix}$$

$\Downarrow \leftarrow \text{Diagonalization, } \theta_{\tilde{t}}$

$$(\tilde{t}_1, \tilde{t}_2) \begin{pmatrix} m_{\tilde{t}_1}^2 & 0 \\ 0 & m_{\tilde{t}_2}^2 \end{pmatrix} \begin{pmatrix} \tilde{t}_1 \\ \tilde{t}_2 \end{pmatrix}$$

$X_t = A_t - \mu \cot \beta$; large mixing possible

- ⇒ Physical parameters: $m_{\tilde{t}_1}, m_{\tilde{t}_2}, \theta_{\tilde{t}}$
- ⇒ Soft SUSY-breaking parameters: $M_{\tilde{t}_L}, M_{\tilde{t}_R}, A_t$
- ⇒ Soft SUSY-breaking parameters determine SUSY mass patterns

Enlarged Higgs sector: Two Higgs doublets

$$H_1 = \begin{pmatrix} H_1^1 \\ H_1^2 \end{pmatrix} = \begin{pmatrix} v_1 + (\phi_1 + i\chi_1)/\sqrt{2} \\ \phi_1^- \end{pmatrix}$$

$$H_2 = \begin{pmatrix} H_2^1 \\ H_2^2 \end{pmatrix} = \begin{pmatrix} \phi_2^+ \\ v_2 + (\phi_2 + i\chi_2)/\sqrt{2} \end{pmatrix}$$

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2 (\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$

$$+ \underbrace{\frac{g'^2 + g^2}{8}}_{\text{gauge couplings, in contrast to SM}} (H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g^2}{2}}_{\text{gauge couplings, in contrast to SM}} |H_1 \bar{H}_2|^2$$

physical states: h^0, H^0, A^0, H^\pm

Goldstone bosons: G^0, G^\pm

Input parameters: (to be determined experimentally)

$$\tan \beta = \frac{v_2}{v_1}, \quad M_A^2 = -m_{12}^2 (\tan \beta + \cot \beta)$$

Contrary to the SM:

m_h is not a free parameter

MSSM tree-level bound: $m_h < M_Z$, excluded by LEP Higgs searches

Large radiative corrections:

Dominant one-loop corrections:

$$\Delta m_h^2 \sim G_\mu m_t^4 \ln \left(\frac{m_{\tilde{t}_1} m_{\tilde{t}_2}}{m_t^2} \right)$$

The MSSM Higgs sector is connected to all other sector via loop corrections
(especially to the scalar top sector)

Measurement of m_h , Higgs couplings \Rightarrow test of the theory

LHC: $\Delta m_h \approx 0.2$ GeV

ILC: $\Delta m_h \approx 0.05$ GeV

Upper bound on m_h in the MSSM:

“Unconstrained MSSM”:

M_A , $\tan \beta$, 5 parameters in \tilde{t} – \tilde{b} sector, μ , $m_{\tilde{g}}$, M_2

$$m_h \lesssim 140 \text{ GeV}$$

for $m_t = 178 \text{ GeV}$

(including theoretical uncertainties from unknown higher orders)
⇒ observable at the LHC

Obtained with:

FeynHiggs

[S.H., W. Hollik, G. Weiglein '98, '00, '02]

[T. Hahn, S.H., W. Hollik, G. Weiglein '03, '04]

www.feynhiggs.de

→ all Higgs masses, couplings, BRs (easy to link, easy to use :-)

Q: Which Lagrangian describes the world?

A: Let's try again . . .

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A: Let's try again . . .

Q': What describes the world better: SM or MSSM ?

A: Two possible ways:

new SUSY particles found
↔
SM ruled out

- Search for new SUSY particles

Problem:

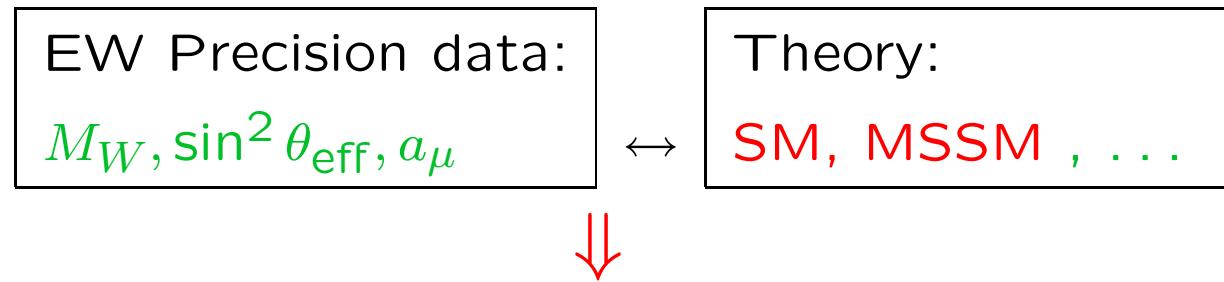
SUSY particles are too heavy for todays colliders, only upper limits of $\mathcal{O}(100 \text{ GeV})$.

- waiting for Tevatron (2006/07 . . . ?)
- waiting for LHC (2008/09 . . . ?)

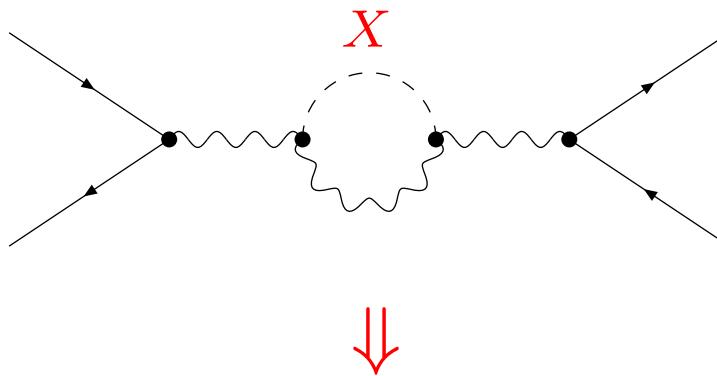
- Search for indirect effects of SUSY via Precision Observables

Precision Observables (POs):

Comparison of electro-weak precision observables with theory:



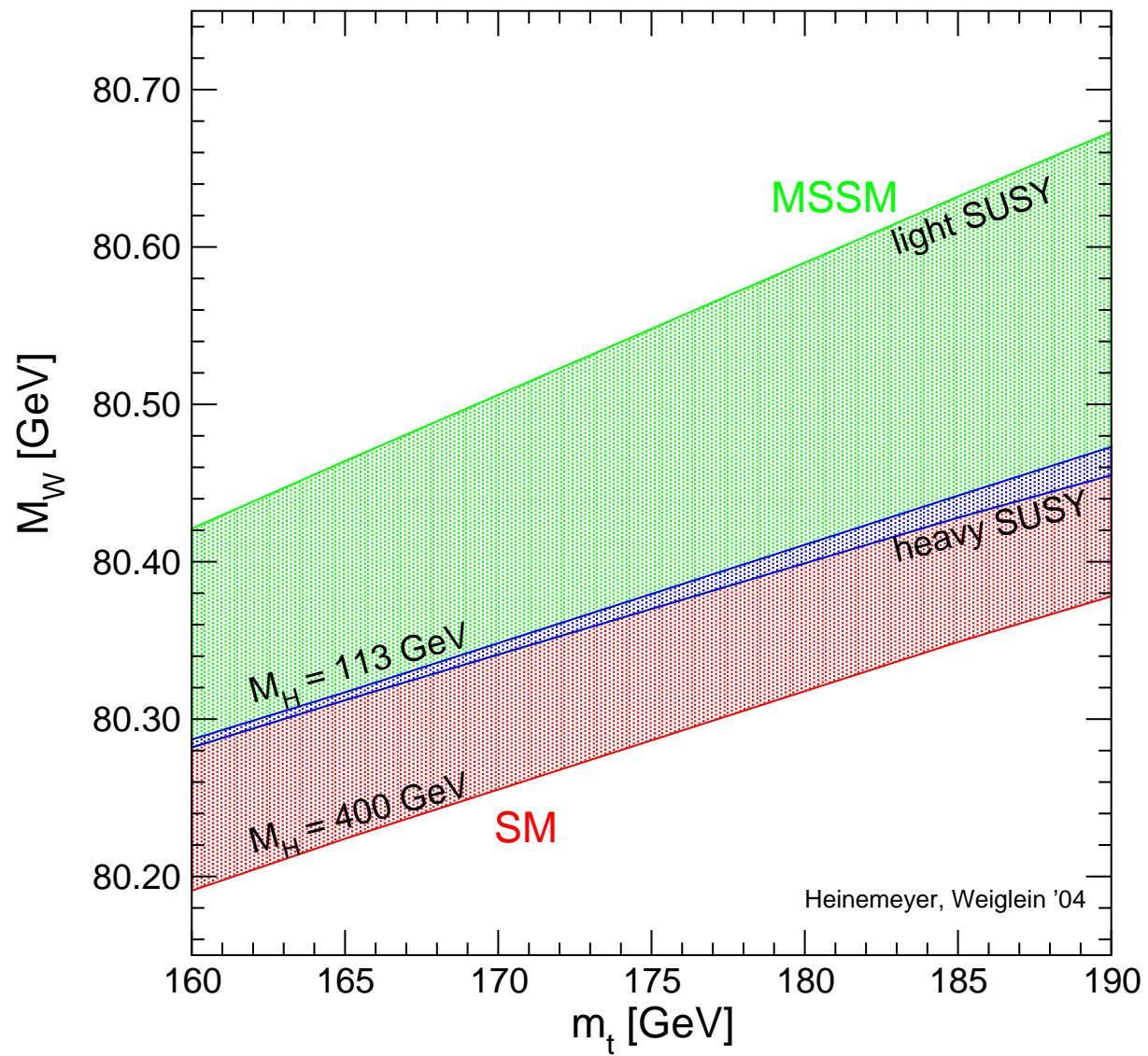
Test of theory at quantum level: **Sensitivity to loop corrections**



Very high accuracy of measurements and theoretical predictions needed

- Which model fits better?
- Does the prediction of a model contradict the experimental data?

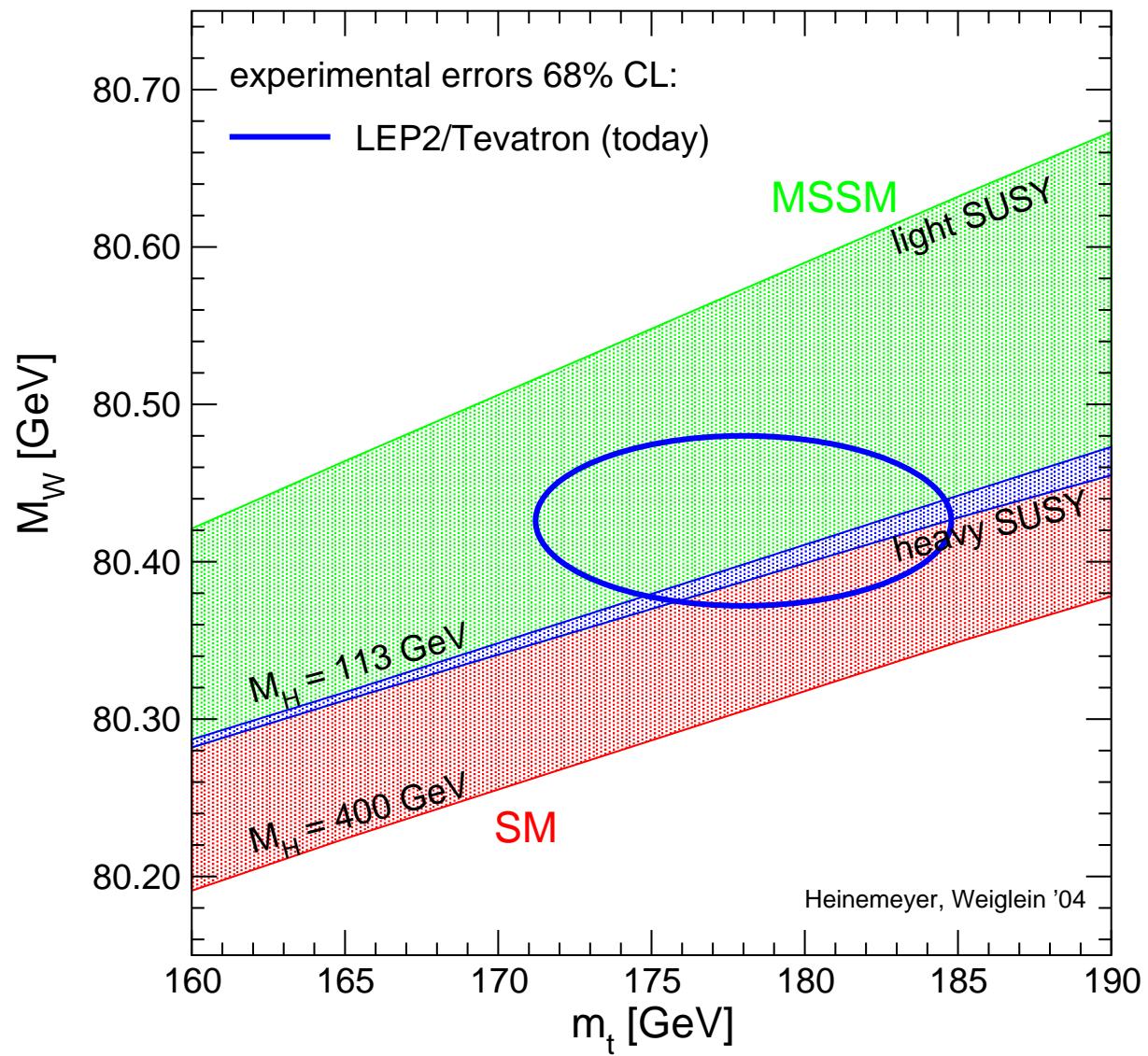
Example: Prediction for M_W in the SM and the MSSM :



MSSM uncertainty:
unknown masses
of SUSY particles

SM uncertainty:
unknown Higgs mass

Example: Prediction for M_W in the SM and the MSSM :



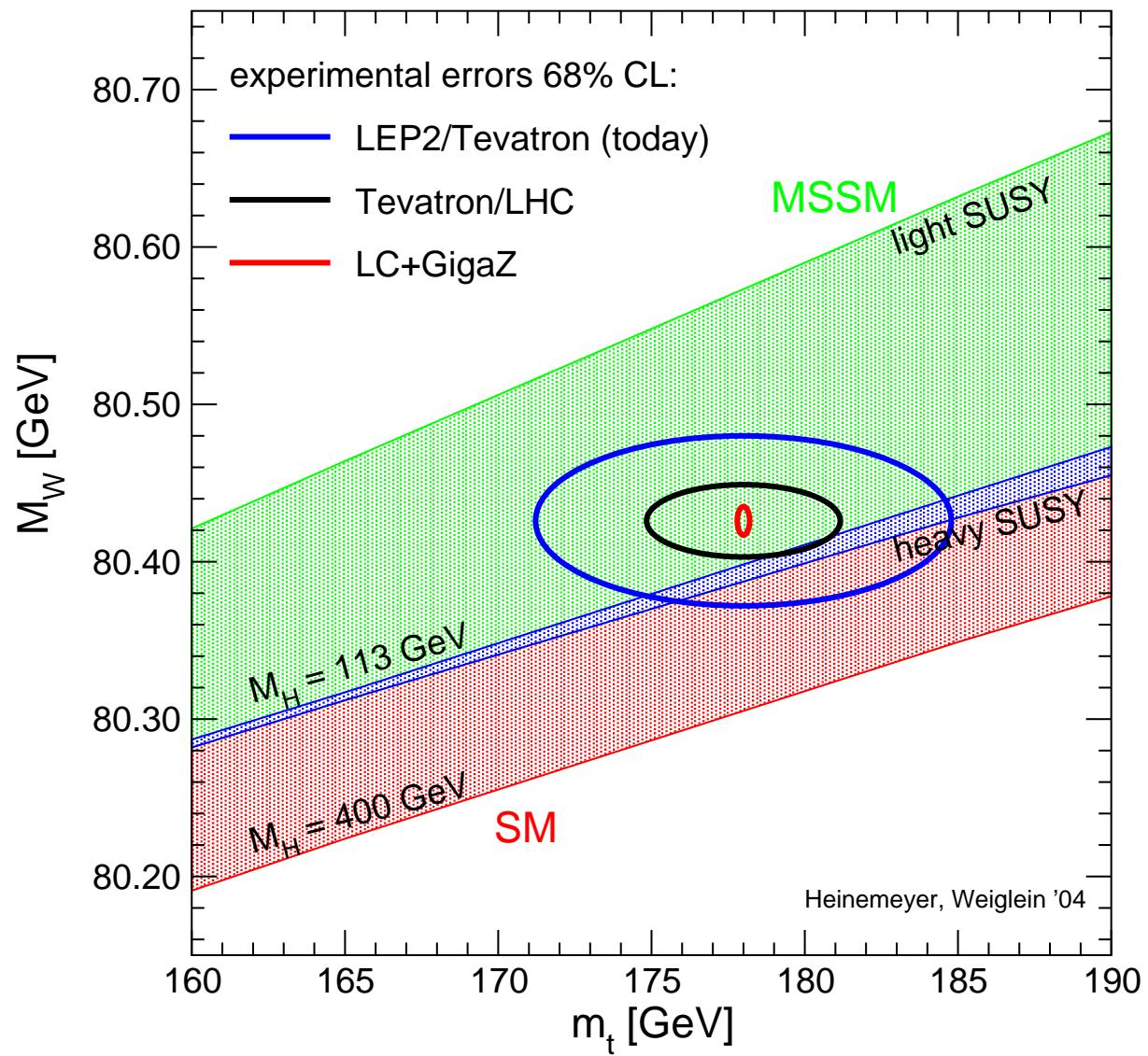
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Example: Prediction for M_W in the SM and the MSSM :



MSSM uncertainty:

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unknown Higgs mass

2. Precision Observables in the MSSM

Precision observables: M_W , $\sin^2 \theta_{\text{eff}}$, m_h , $(g - 2)_\mu$, b physics, . . .

- 1.) Theoretical prediction for M_W in terms of $M_Z, \alpha, G_\mu, \Delta r$:

$$M_W^2 \left(1 - \frac{M_W^2}{M_Z^2} \right) = \frac{\pi \alpha}{\sqrt{2} G_\mu} \left(\frac{1}{1 - \Delta r} \right)$$

\Updownarrow
loop corrections

- 2.) Effective mixing angle:

$$\sin^2 \theta_{\text{eff}} = \frac{1}{4 |Q_f|} \left(1 - \frac{\text{Re } g_V^f}{\text{Re } g_A^f} \right)$$

Higher order contributions:

$$g_V^f \rightarrow g_V^f + \Delta g_V^f, \quad g_A^f \rightarrow g_A^f + \Delta g_A^f$$

Corrections to M_W , $\sin^2 \theta_{\text{eff}}$

→ can be approximated with the **ρ -parameter**:

ρ measures the relative strength between
neutral current interaction and charged current interaction

$$\rho = \frac{1}{1 - \Delta\rho} \quad \Delta\rho = \frac{\Sigma_Z(0)}{M_Z^2} - \frac{\Sigma_W(0)}{M_W^2}$$

(leading, process independent terms)

$\Delta\rho$ gives the main contribution to EW observables:

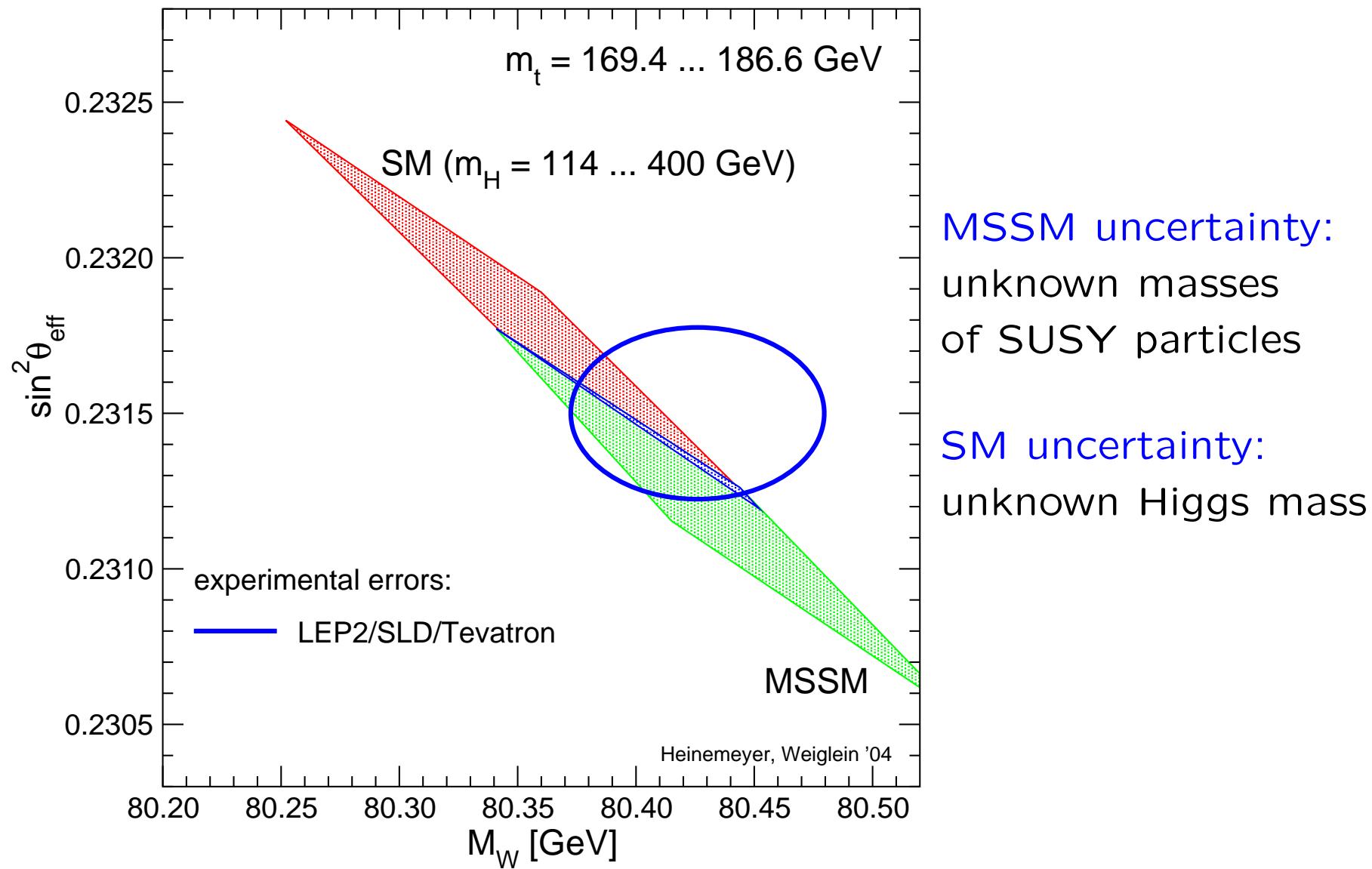
$$\Delta M_W \approx \frac{M_W}{2} \frac{c_W^2}{c_W^2 - s_W^2} \Delta\rho,$$

$$\Delta \sin^2 \theta_W^{\text{eff}} \approx - \frac{c_W^2 s_W^2}{c_W^2 - s_W^2} \Delta\rho$$

⇒ Experimental bound: $\Delta\rho \lesssim 2 \times 10^{-3}$

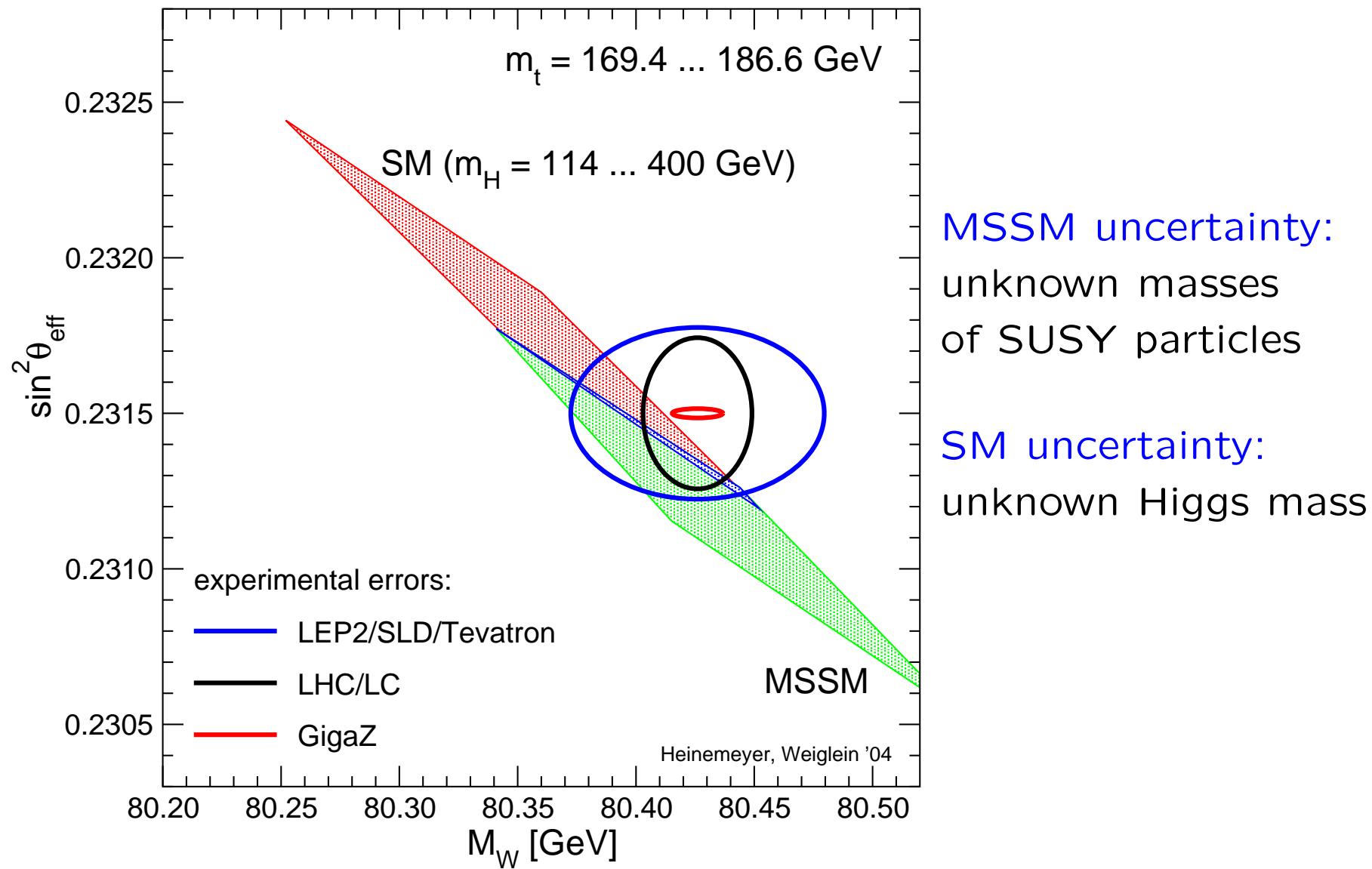
Example of application:

Prediction for M_W and $\sin^2 \theta_{\text{eff}}$ in the SM and the MSSM :



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Prediction for M_W and $\sin^2 \theta_{\text{eff}}$ in the SM and the MSSM :



MSSM uncertainty:

unknown masses
of SUSY particles

SM uncertainty:

unknown Higgs mass

These are the current prediction. But what about the **ERRORS** ?

Three different types of errors:

Experimental error (\Rightarrow included in the figure):

- current error
- future expectations

\Rightarrow sets the scale, has to be matched by other errors

Theory error:

\Rightarrow error due to missing higher order corrections

- only estimates possible
- even more complicated for the future

Parametric error:

- current uncertainty in the prediction due to error in the input parameters
- future uncertainty

\Rightarrow focus on SM parameters

\Rightarrow derive information about (unknown) SUSY parameters
(SUSY parametric uncertainties highly model dependent)

Current and future errors:

Current:

$$\delta M_W^{\text{theory}} \approx \pm 10 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{theory}} \approx \pm 10 \times 10^{-5}$$

$$\delta m_t : \quad \delta M_W^{\text{para}} \approx \pm 26 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{para}} \approx \pm 14 \times 10^{-5}$$

$$\delta(\Delta\alpha_{\text{had}}) : \quad \delta M_W^{\text{para}} \approx \pm 6.5 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{para}} \approx \pm 13 \times 10^{-5}$$

$$\delta M_W^{\text{exp}} \approx \pm 34 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{exp}} \approx \pm 16 \times 10^{-5}$$

Future:

$$\delta M_W^{\text{theory}} \gtrsim \pm 2 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{theory}} \gtrsim \pm 2 \times 10^{-5}$$

$$\delta m_t : \quad \delta M_W^{\text{para}} \approx \pm 1 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{para}} \approx \pm 0.4 \times 10^{-5}$$

$$\delta(\Delta\alpha_{\text{had}}) : \quad \delta M_W^{\text{para}} \approx \pm 1 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{para}} \approx \pm 1.8 \times 10^{-5}$$

$$[\text{GigaZ}] : \quad \delta M_W^{\text{exp}} \approx \pm 7 \text{ MeV}, \quad \delta \sin^2 \theta_{\text{eff}}^{\text{exp}} \approx \pm 1.3 \times 10^{-5}$$

(SUSY parametric errors depend strongly on the scenario)

⇒ M_W under control, $\sin^2 \theta_{\text{eff}}$ barely precise enough

3.) Theoretical prediction of the lightest MSSM Higgs boson mass: m_h

Contrary to the SM: m_h is not a free parameter

MSSM tree-level bound: $m_h < M_Z$, excluded by LEP Higgs searches

Large radiative corrections:

Dominant one-loop corrections: $\sim G_\mu m_t^4 \ln \left(\frac{m_{\tilde{t}_1} m_{\tilde{t}_2}}{m_t^2} \right)$

The MSSM Higgs sector is connected to all other sector via loop corrections
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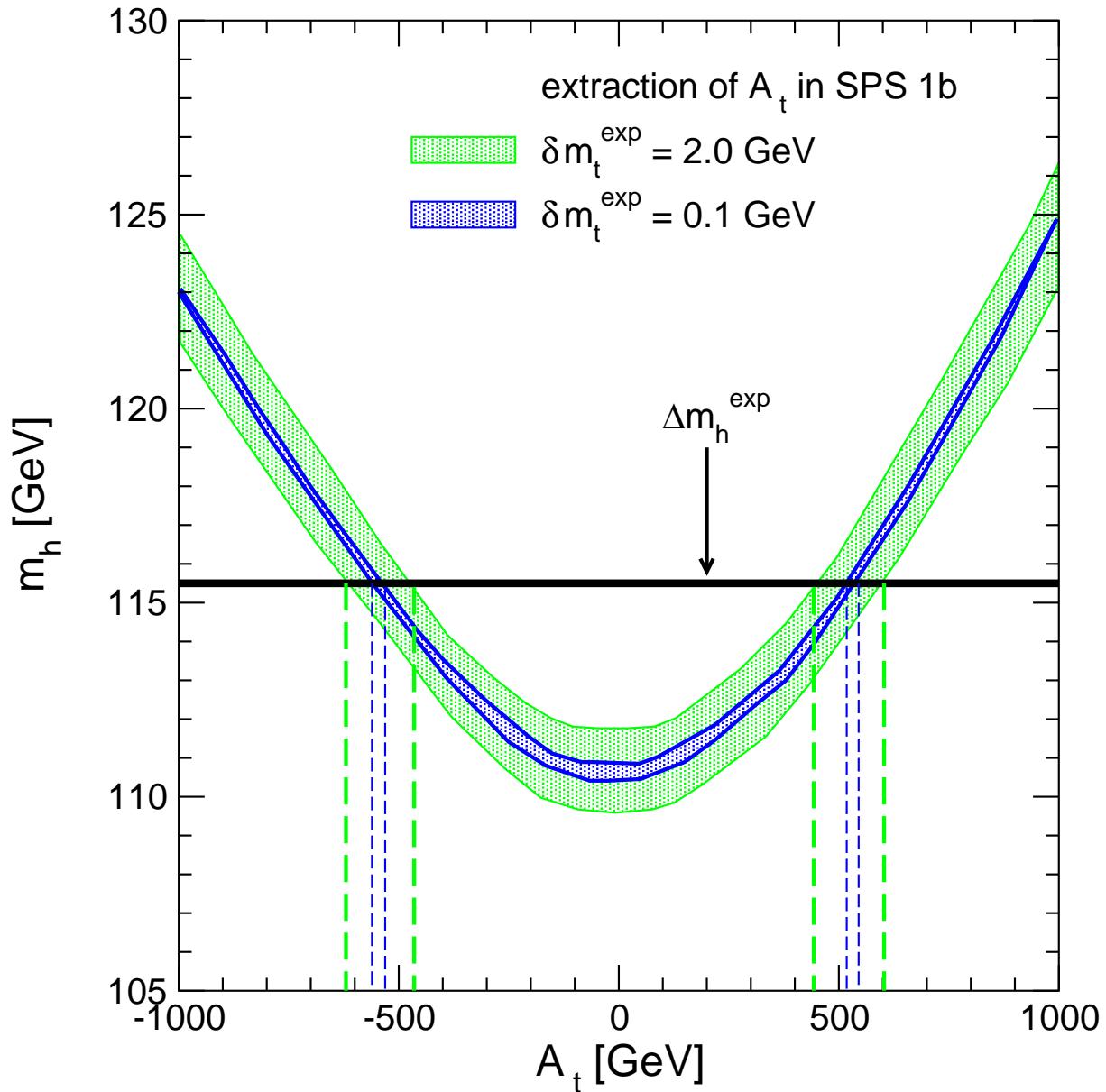
Measurement of m_h , Higgs couplings \Rightarrow test of the theory

LHC: $\Delta m_h \approx 0.2$ GeV

ILC: $\Delta m_h \approx 0.05$ GeV

$\Rightarrow m_h$ will be (the best?) electroweak precision observable

Example of application: m_h prediction as a function of A_t



Remaining higher-order uncertainties:

[*G. Degrassi, S.H., W. Hollik, P. Slavich, G. Weiglein '02*]

2-loop momentum independent:

remaining 2-loop, $q^2 = 0$: $\Delta m_h \lesssim 1.5 \text{ GeV}$

2-loop momentum dependent:

2-loop: $\Delta m_h \lesssim 1 \text{ GeV}$

t/\tilde{t} : 3-loop, 4-loop, ...:

$\Rightarrow \Delta m_h \lesssim 1.5 \text{ GeV}$

b/\tilde{b} : 3-loop, 4-loop, ...:

$\Rightarrow \Delta m_h \lesssim 0 - 3 \text{ GeV}$ (depending on parameter space)

[*S.H., W. Hollik, H. Rzehak, G. Weiglein '04*]

full intrinsic error: (from unknown higher-order corrections)

today: $\Delta m_h^{\text{intr}} \approx 3 \text{ GeV}$ (depending on parameter space)

needed for future: $\Delta m_h^{\text{intr}} \lesssim 0.5 - 0.1 \text{ GeV}$

Parametric uncertainties:

m_t :

today: $\delta m_t^{\text{Tevatron}} \approx 4 \text{ GeV} \Rightarrow \Delta m_h^{m_t} \approx 4 \text{ GeV}$

future: $\delta m_t^{\text{LHC}} \approx 1 - 2 \text{ GeV} \Rightarrow \Delta m_h^{m_t} \approx 1 - 2 \text{ GeV} \Rightarrow \text{not sufficient!}$

$\delta m_t^{\text{ILC}} \approx 100 \text{ MeV} \Rightarrow \Delta m_h^{m_t} \approx 100 \text{ MeV}$

m_b : $\delta m_b \lesssim 100 \text{ MeV} \Rightarrow \text{negligible}$

M_W :

today: $\delta M_W = 34 \text{ MeV} \Rightarrow \Delta m_h^{M_W} \approx 100 \text{ MeV}$

future: $\delta M_W^{\text{GigaZ}} \approx 7 \text{ MeV}$ negligible

α_s :

today: $\delta \alpha_s(M_Z) \approx 0.002 \Rightarrow \Delta m_h^{\alpha_s} \approx 0.3 \text{ GeV}$

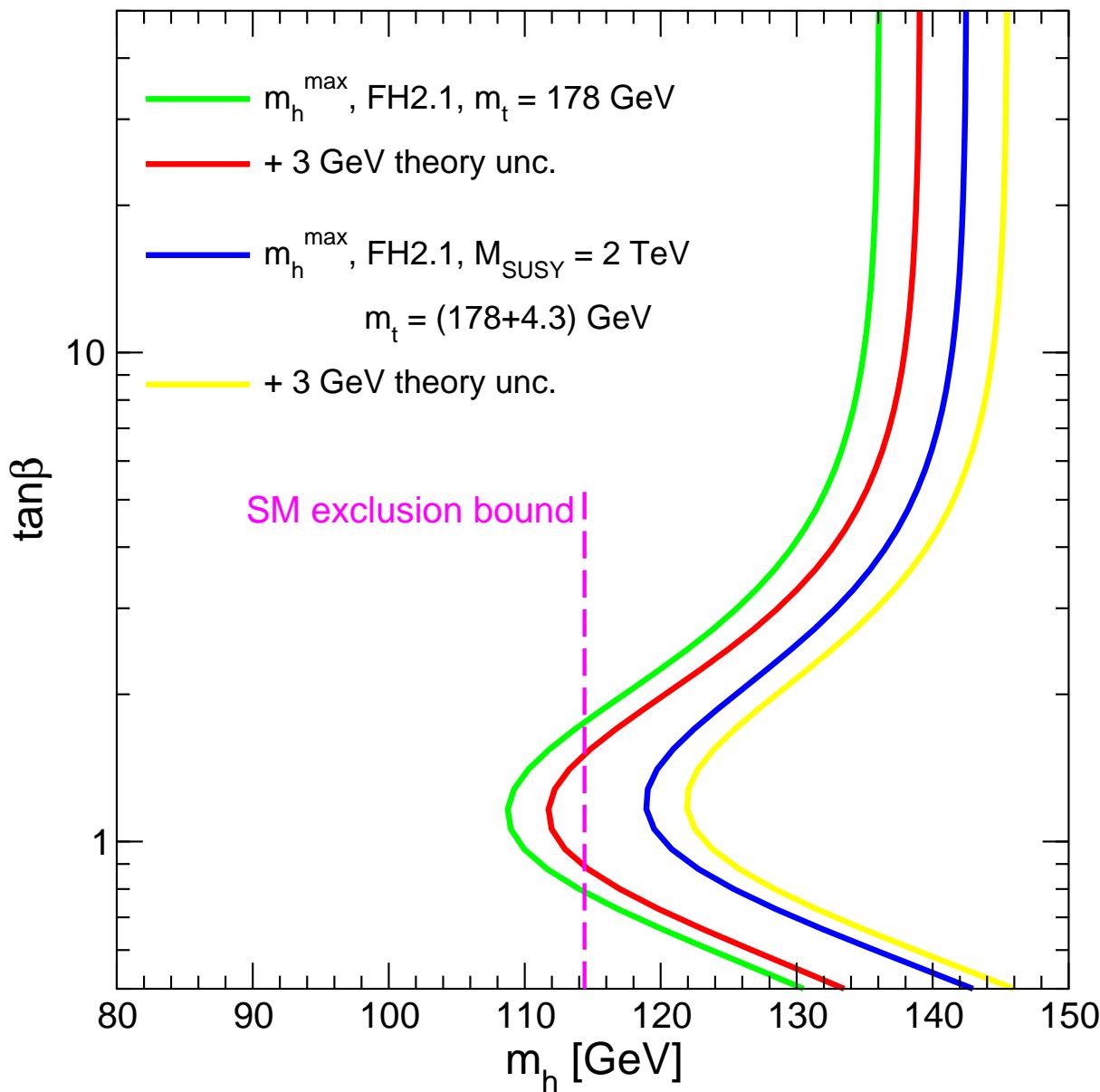
future: $\delta \alpha_s(M_Z) \lesssim 0.001 \Rightarrow \Delta m_h^{\alpha_s} \approx 0.1 - 0.2 \text{ GeV}$

Experimental uncertainties:

$\Delta m_h^{\text{exp,LHC}} \approx 200 \text{ MeV}$

$\Delta m_h^{\text{exp,ILC}} \approx 50 \text{ MeV} \Rightarrow \text{can hardly be matched (we do our best!)}$

Example I: effect on $\tan\beta$ exclusion:



compare:

m_h^{\max} scenario, *FeynHiggs2.1*,
 $m_t = 178 \text{ GeV}$

m_h^{\max} scenario, *FeynHiggs2.1*,
3 GeV theory unc.

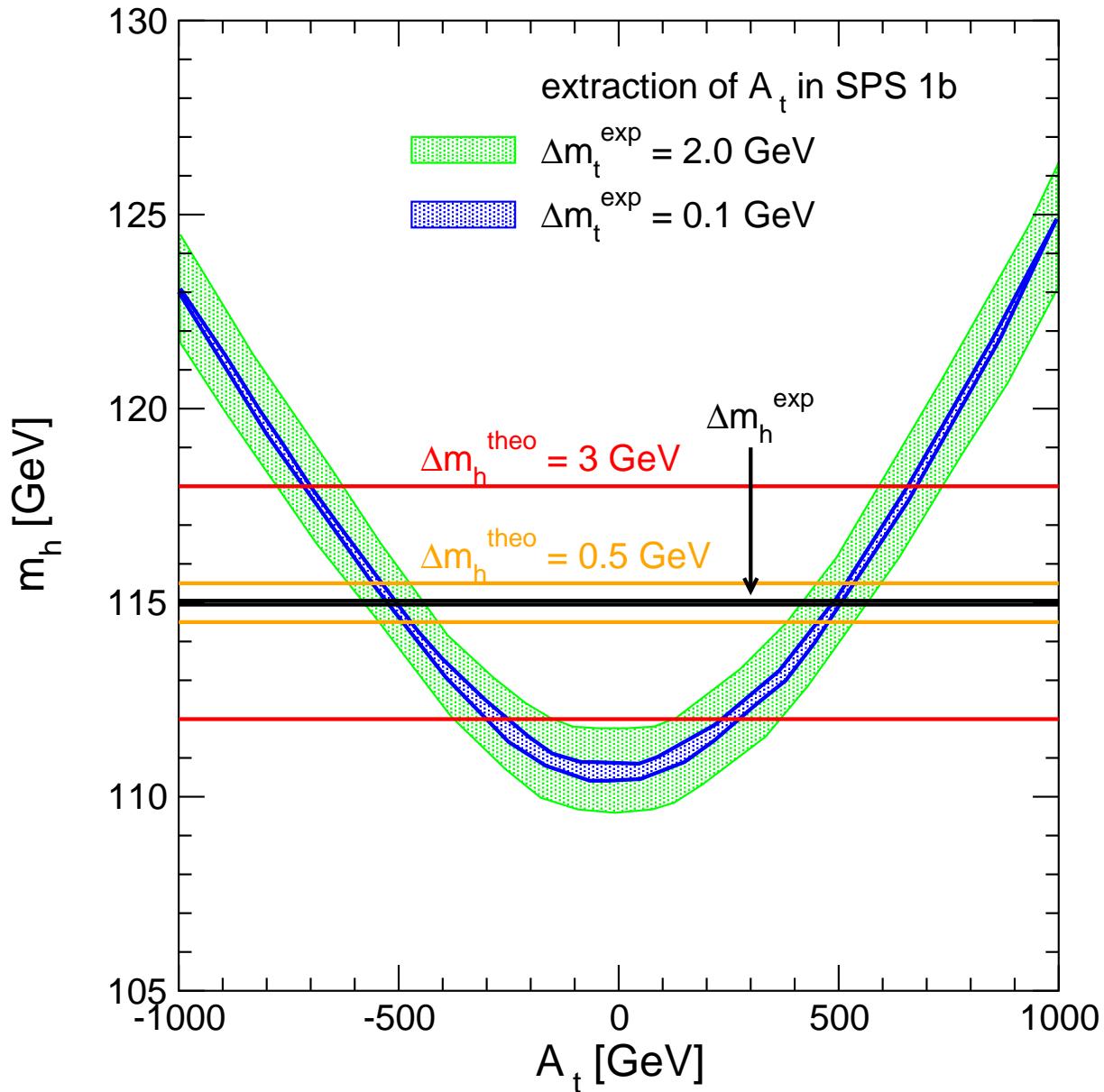
$\Rightarrow \tan\beta$ bound considerably
weakened

even worse:

m_h^{\max} scenario with
 $m_t = 182.3, M_{\text{SUSY}} = 2 \text{ TeV}$

m_h^{\max} scenario with
 $m_t = 182.3, M_{\text{SUSY}} = 2 \text{ TeV}$
+ 3 GeV theory unc.

Example II: m_h prediction as a function of A_t



SPS1b:

$m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{b}_1}, m_{\tilde{b}_2}$ known,
 A_t unknown

$\tan \beta, M_A$ known,
realistic experimental
errors assumed

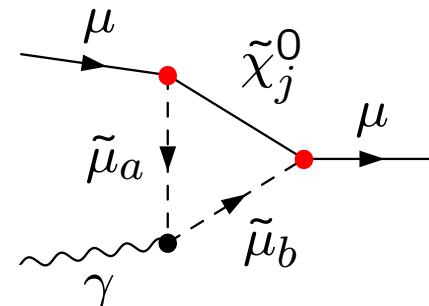
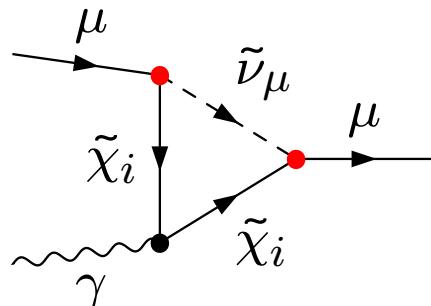
⇒ extraction of A_t possible
⇒ Δm_h^{theo} has to be
under control

4.) Prediction of the anomalous magnetic moment of the muon: $(g - 2)_\mu$

Coupling of muon to magnetic field : $\mu - \mu - \gamma$ coupling

$$\bar{u}(p') \left[\gamma^\mu F_1(q^2) + \frac{i}{2m_\mu} \sigma^{\mu\nu} q_\nu F_2(q^2) \right] u(p) A_\mu \quad F_2(0) = (g - 2)_\mu$$

Feynman diagrams for MSSM 1L corrections:



Enhancement factor as compared to SM:

$$\begin{aligned} \mu - \tilde{\chi}_i^\pm - \tilde{\nu}_\mu &: \sim m_\mu \tan \beta \\ \mu - \tilde{\chi}_j^0 - \tilde{\mu}_a &: \sim m_\mu \tan \beta \end{aligned}$$

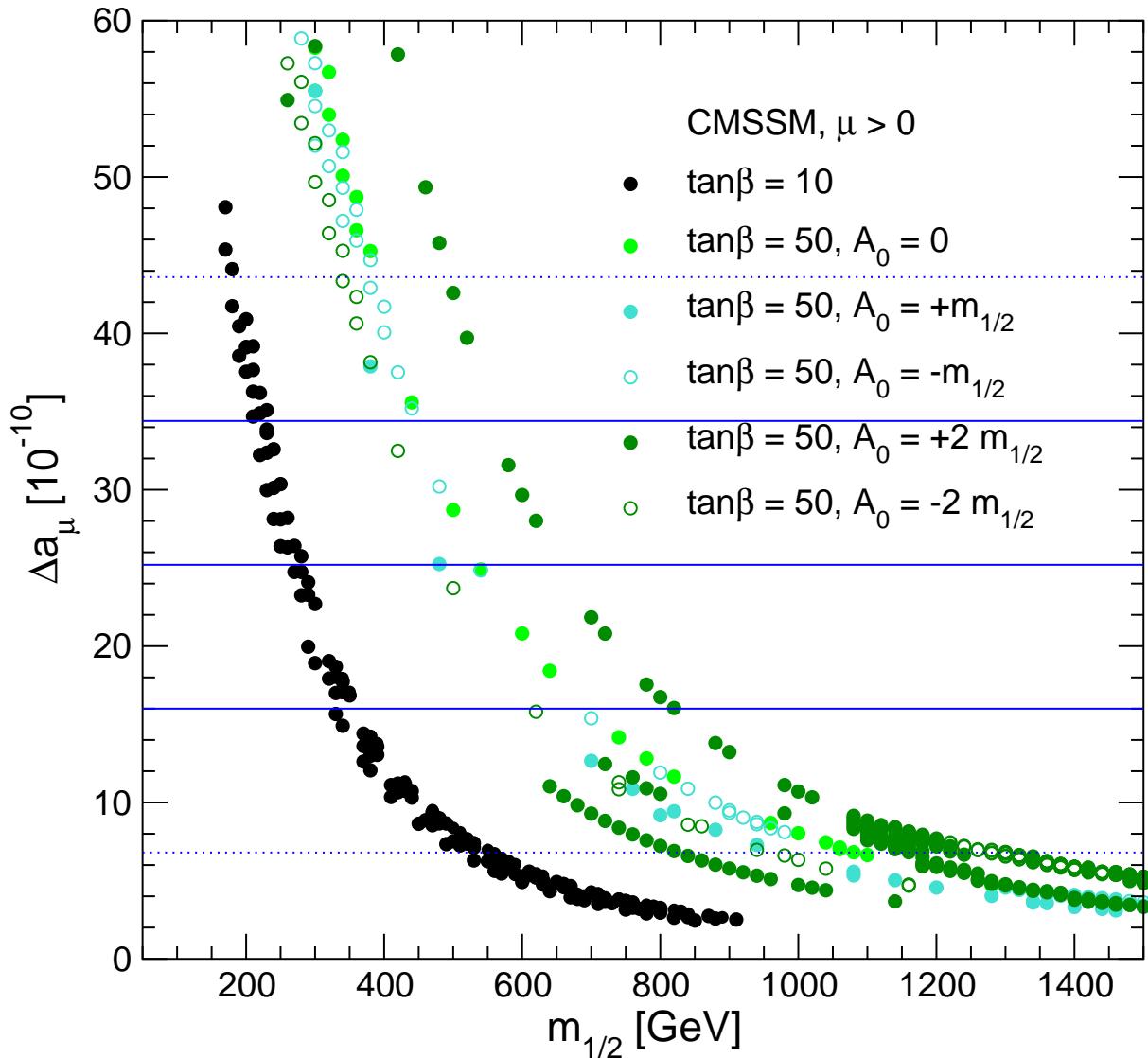
Overview of the SM theory evaluation:

Source	contr. to $a_\mu [10^{-10}]$	
LO hadr.	$\sim 695 \pm 7$ (e^+e^-)	[Davier et al, Hagiwara et al. '03]
		[Ghozzi, Jegerlehner '03]
LBL	711.0 ± 6 (τ)	[Davier, Eideman, Höcker, Zhang '03]
	8 ± 4	[Knecht, Nyffeler '02]
EW 1L	13.6 ± 2.5 tbc	[Melnikov, Vainshtein '03]
	19	
EW 2L	-4	[Czarnecki, Krause, Marciano '98]
exp. res.	6	[BNL E821 '04]

- “Isospin breaking effects” in τ data problematic [Ghozzi, Jegerlehner '03]
- KLOE data (radiative return) agrees with e^+e^- data
- ⇒ general agreement at ICHEP'04 Beijing: discard τ data

$$a_\mu^{\text{exp}} - a_\mu^{\text{theo,SM}} \approx (25.2 \pm 9.2) \times 10^{-10}$$

Example: Investigation of mSUGRA with cold dark matter constraint



Scan over $m_{1/2}, m_0, A_0$
 $\tan\beta = 10, 50$
selected points give correct
amount of cold dark matter

[Ellis, S.H., Olive, Weiglein '04]

Severe bounds on e.g. $m_{1/2}$

Remaining uncertainties:

1. SUSY 1L diagrams with a mixed f/\tilde{f} loop

- same enhancement factors as
SM 1L diagrams with a closed f/\tilde{f} loop attached
- ⇒ possibly of similar order

2. THDM corrections to SUSY 1L diagrams

Already known:

QED corrections to $a_\mu^{\text{SUSY}}(1\text{L})$: $\sim -8\%$ for $M_{\text{SUSY}} = 500 \text{ GeV}$
[*G. Degrassi, G. Giudice '98*]

- only evaluated for a common SUSY mass scale
- ⇒ non-negligible corrections possible

⇒ Remaining uncertainties estimated to $\sim 6 \times 10^{-10}$
[*S.H., D. Stöckinger, G. Weiglein '04*]

3. Precision Observables in the CMSSM: collider implications

What is the “CMSSM” or “mSUGRA” ?

⇒ Scenario characterized by

$$m_0, m_{1/2}, A_0, \tan\beta, \text{sign } \mu$$

m_0 : universal scalar mass parameter

$m_{1/2}$: universal gaugino mass parameter

A_0 : universal trilinear coupling

$\tan\beta$: ratio of Higgs vacuum expectation values

$\text{sign}(\mu)$: sign of supersymmetric Higgs parameter

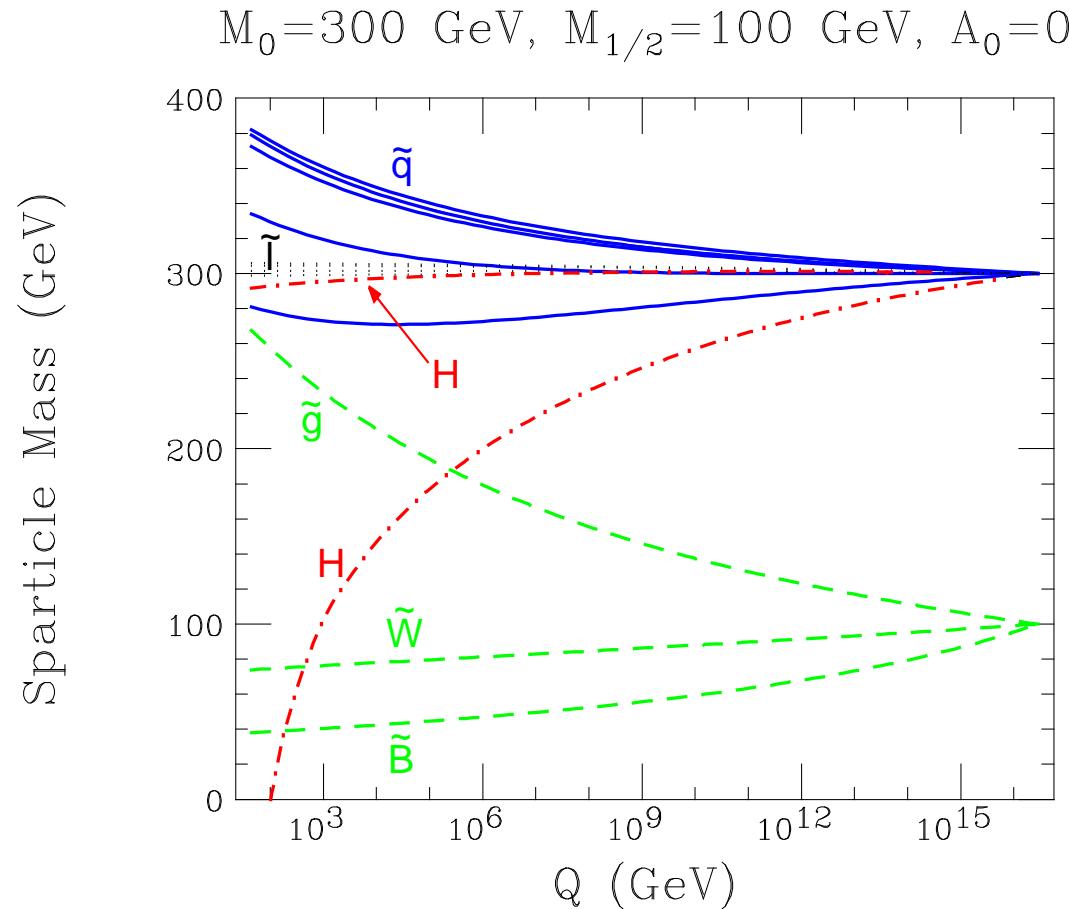
} at the GUT scale

⇒ particle spectra from renormalization group running to weak scale

Lightest SUSY particle (LSP) is usually lightest neutralino

Low-energy parameters (at the electroweak (EW) scale) via
"Renormalization group equations" (RGEs)

[RGE: equations that connect parameters at different energy scales]



Note: one parameter in the Higgs potential becomes negative
⇒ Higgs mechanism for free

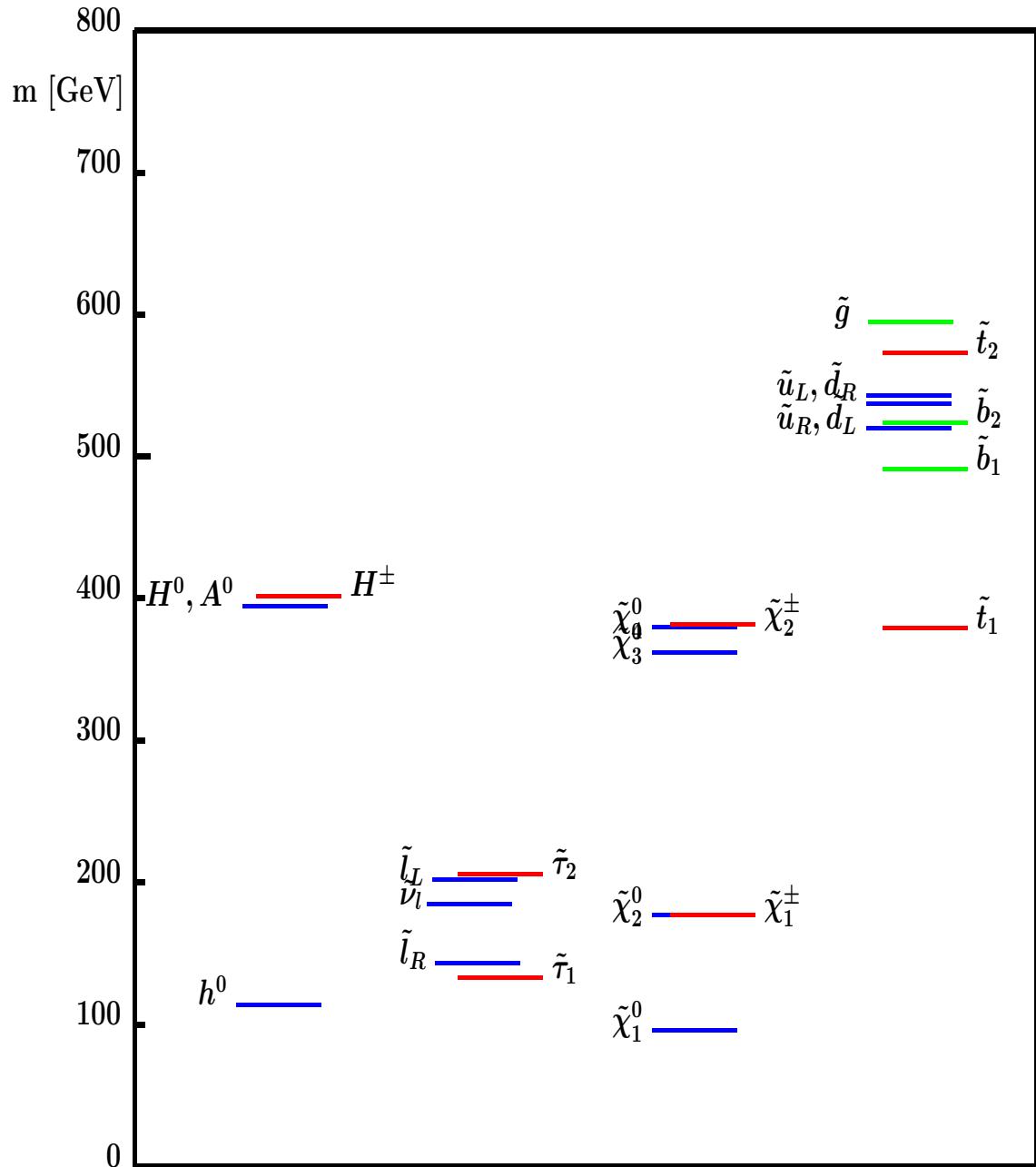
"Typical" CMSSM scenario
 (SPS 1a benchmark scenario):

SPS home page:

www.ippp.dur.ac.uk/~georg/sps

$\Rightarrow m_h \lesssim 130$ GeV

\Rightarrow observable at the Tevatron



Precision Observables in the CMSSM: collider implications

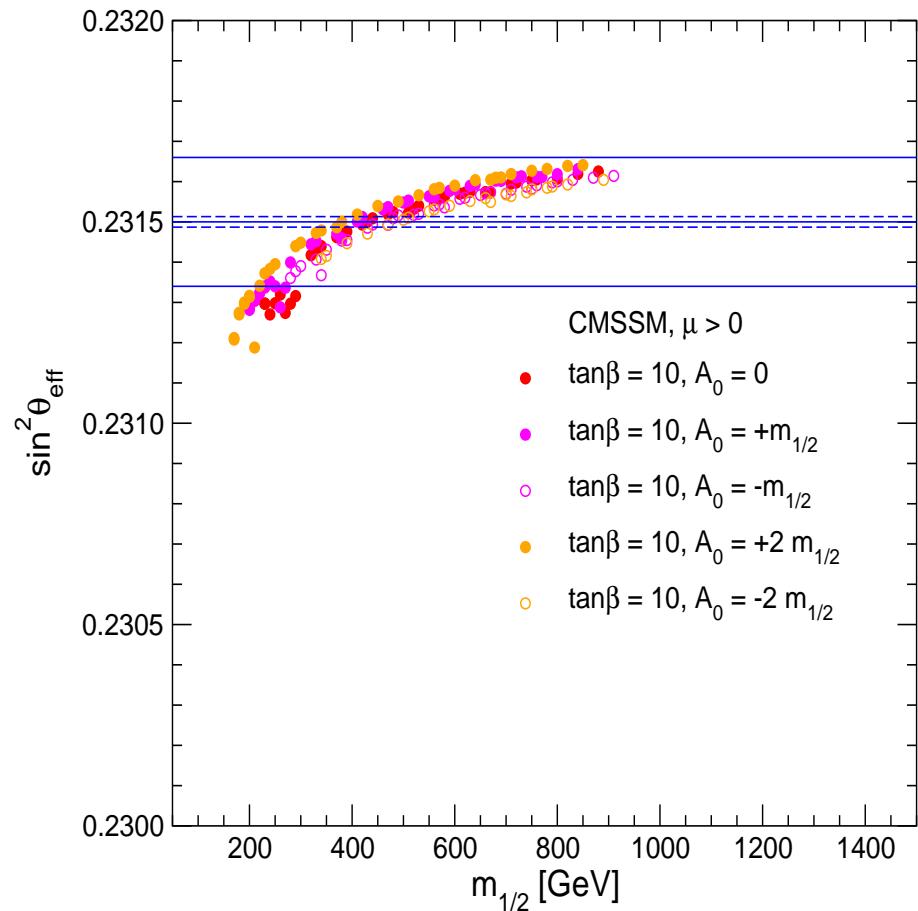
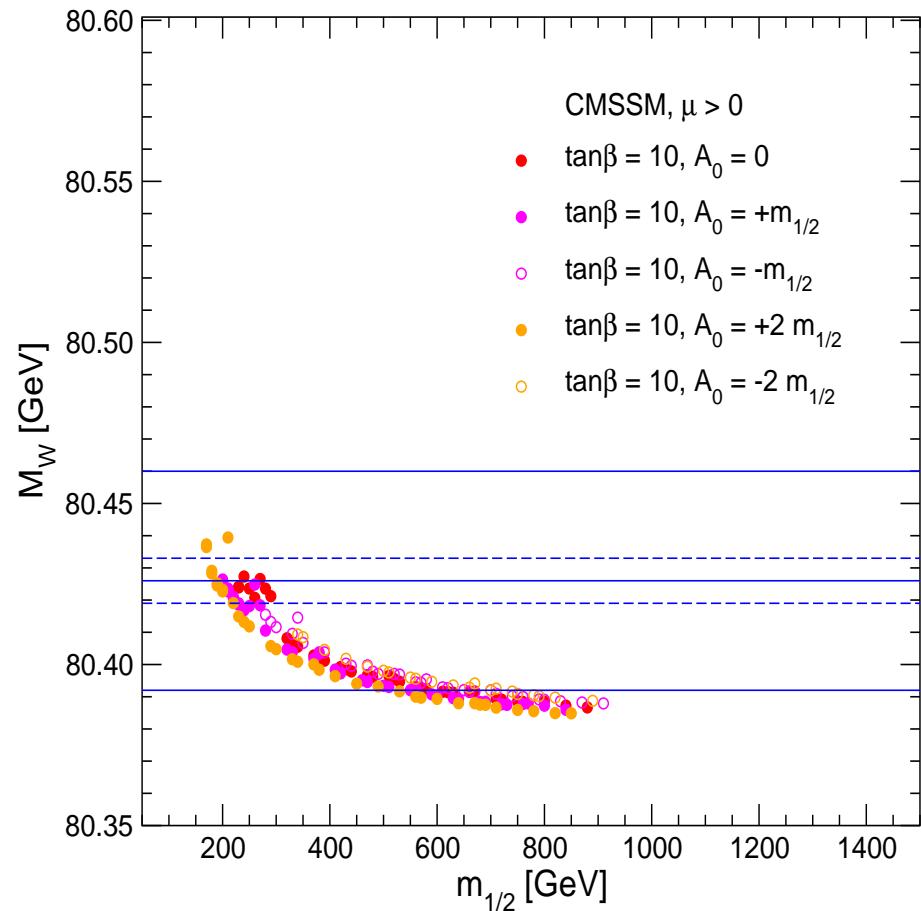
What do we know about the SUSY mass scale?

1. Coupling constant unification $\Rightarrow M_{\text{SUSY}} \approx 1 \text{ TeV}$
2. LSP should be cold dark matter $\Rightarrow M_{\text{SUSY}} \lesssim 1 \text{ TeV}$
3. Indirect hints from existing data?

[J. Ellis, S.H., K. Olive, G. Weiglein '04]

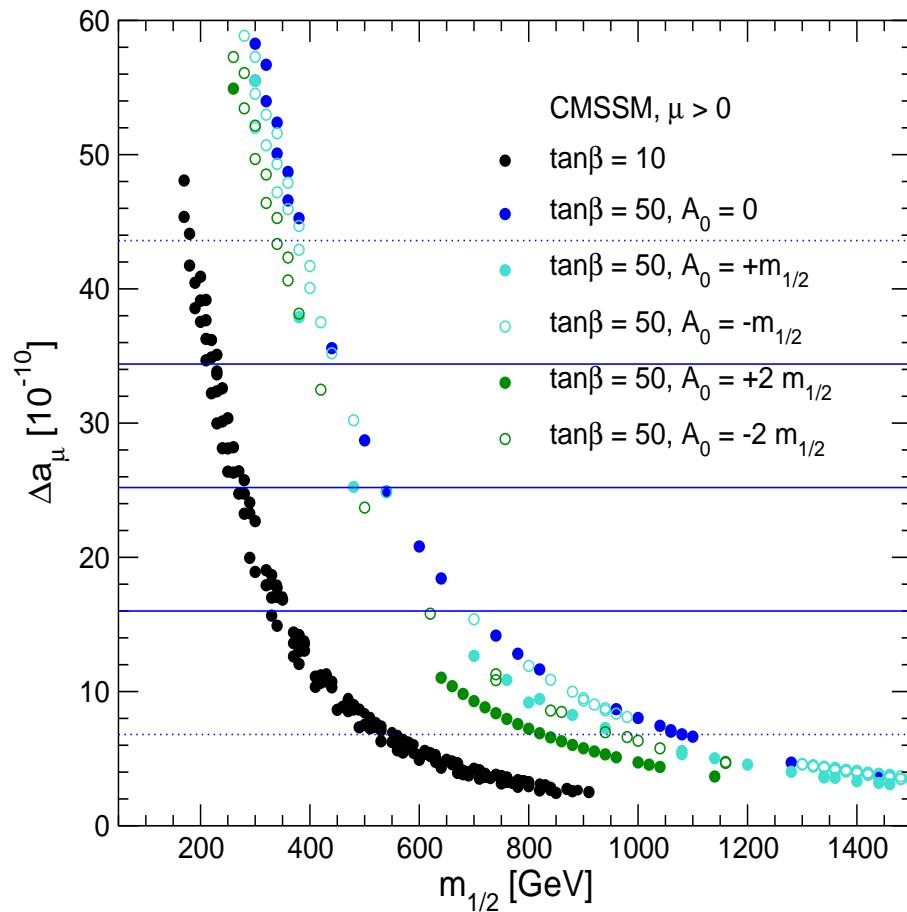
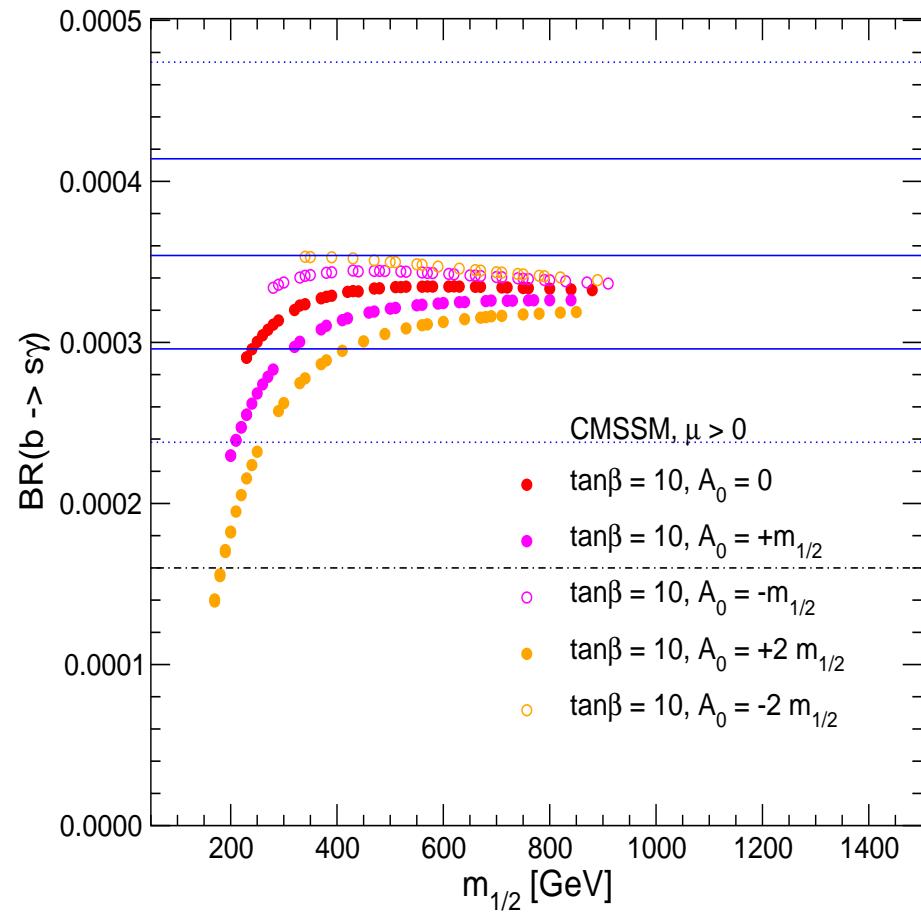
- Focus on mSUGRA/CMSSM
free parameters: $m_{1/2}$, m_0 , A_0 , $\tan \beta$
- hard constraint: LSP gives right amount of cold dark matter
only thin strips allowed in the $m_{1/2}$ – m_0 plane
fix $\tan \beta = 10, 50$ (lower/upper edge in CMSSM) and $\mu > 0$
- Use existing data of M_W , $\sin^2 \theta_{\text{eff}}$, $\text{BR}(b \rightarrow s\gamma)$, $(g - 2)_\mu$
 $\Rightarrow \chi^2$ fit with these observables
determine best fit values of $m_{1/2}$, m_0 , A_0
 \Rightarrow best fit values for masses, couplings, ...

M_W and $\sin^2 \theta_{\text{eff}}$ for $\tan \beta = 10$:



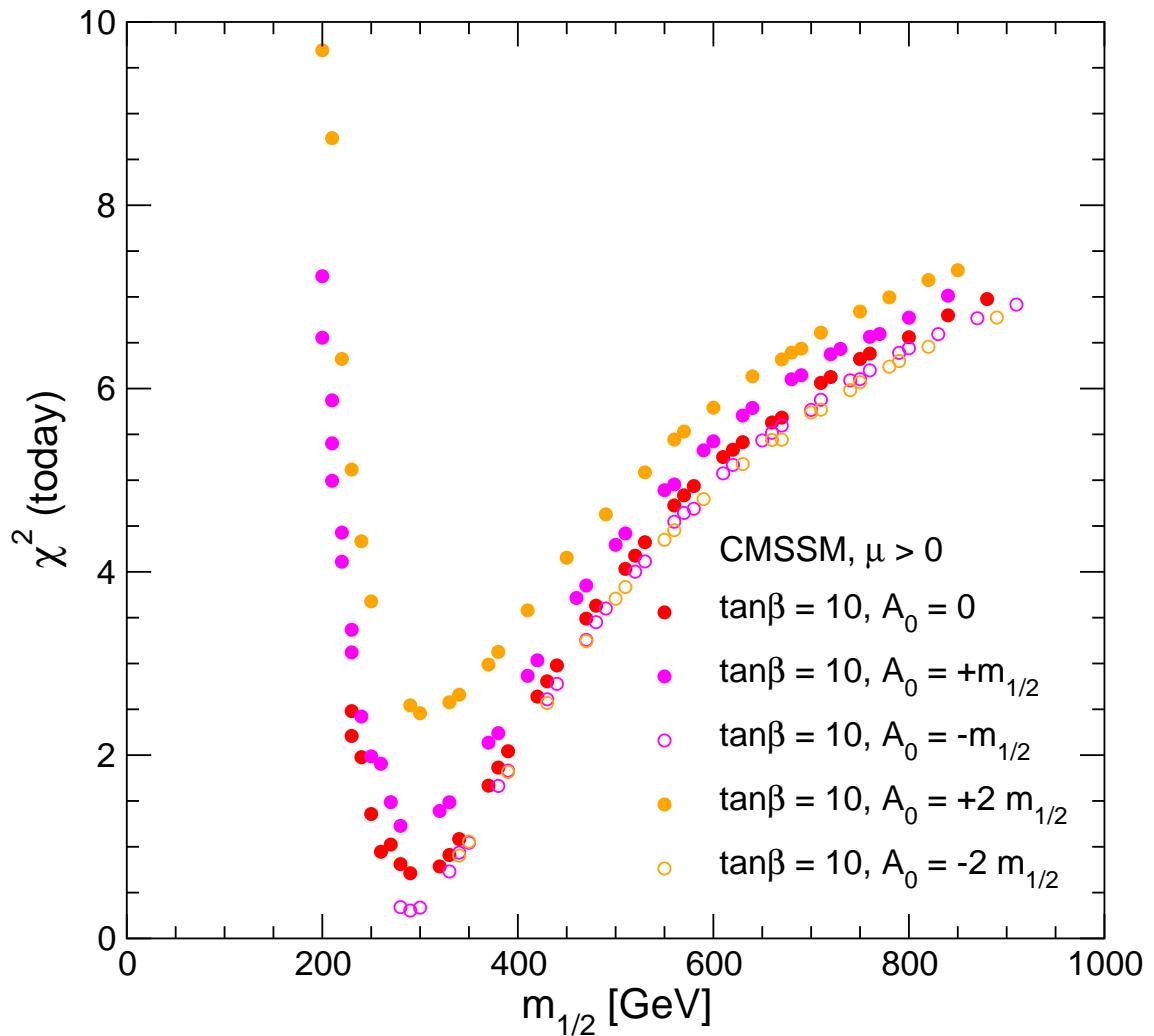
$\Rightarrow m_{1/2} \approx 300 \text{ GeV}$ favored

$\text{BR}(b \rightarrow s\gamma)$ and $(g - 2)_\mu$ (for $\tan\beta = 10$):



$\Rightarrow m_{1/2} \approx 300 \text{ GeV}$ favored

χ^2 fit result for $m_{1/2}$: ($\tan\beta = 10$, $A_0/m_{1/2}$ varied)



Very good fit!

Best fit obtained for

$m_{1/2} \approx 300$ GeV

$A_0 \approx -300$ GeV

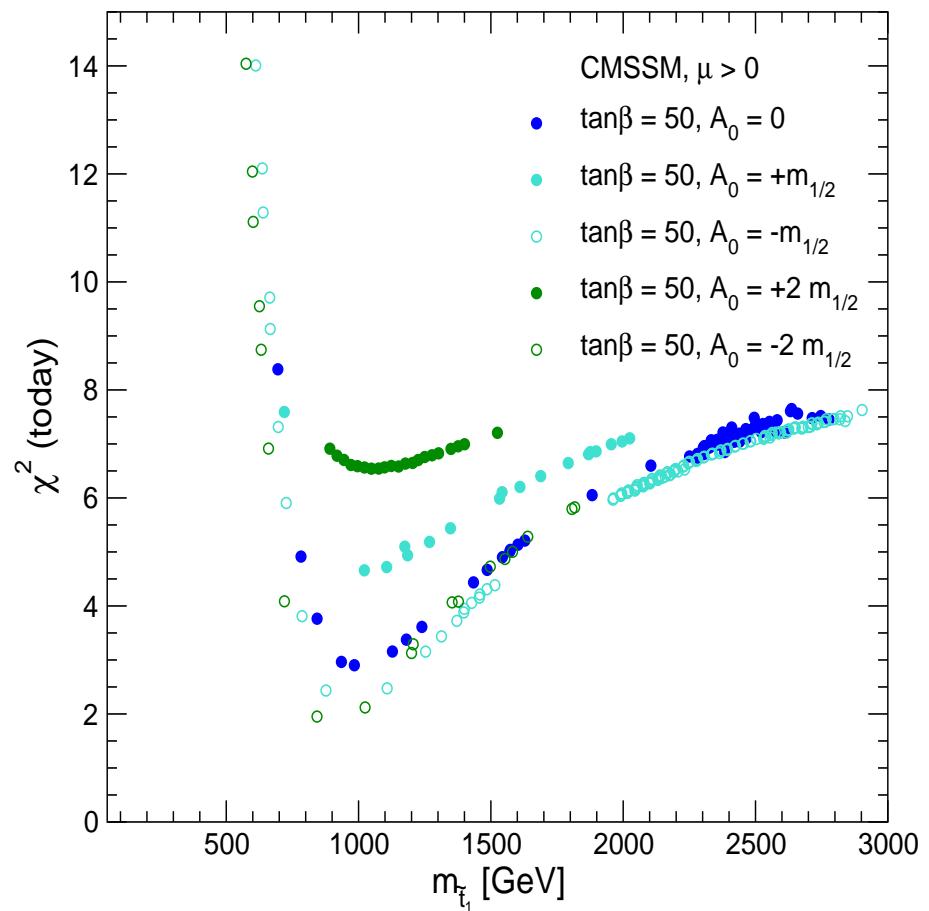
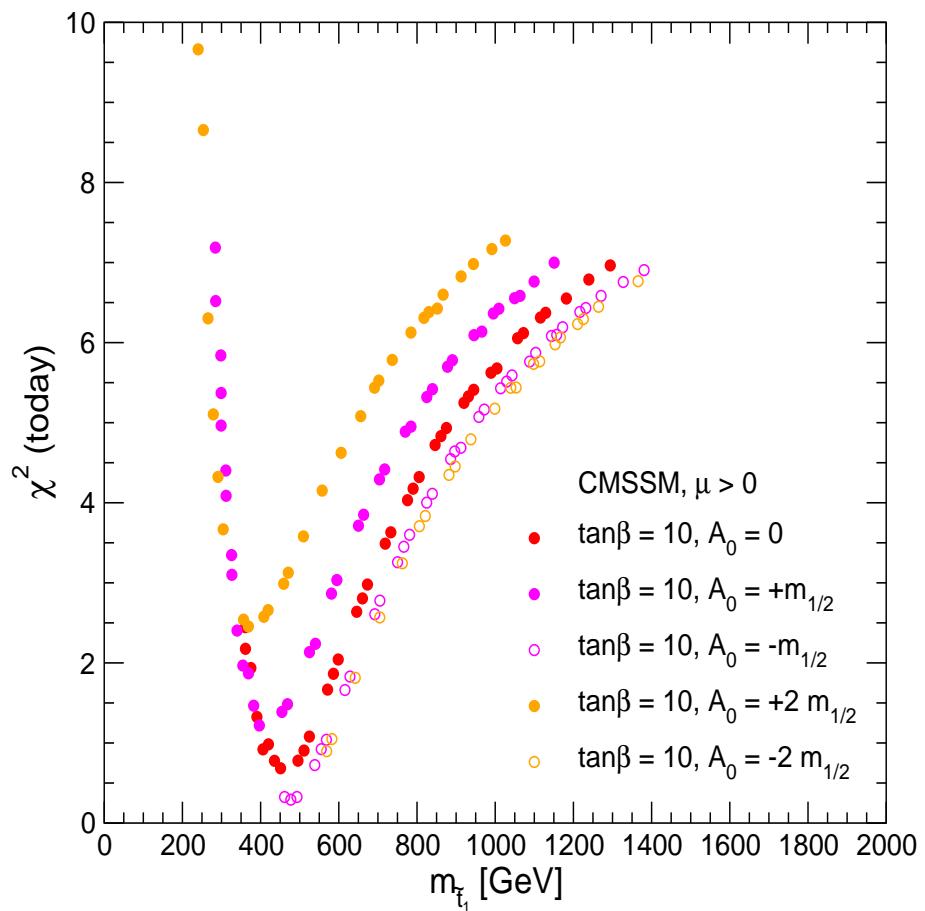
$m_0 \approx 60$ GeV

⇒ SUSY particles relatively light

⇒ very good prospects
for the LHC/ILC

slightly worse for $\tan\beta = 50$

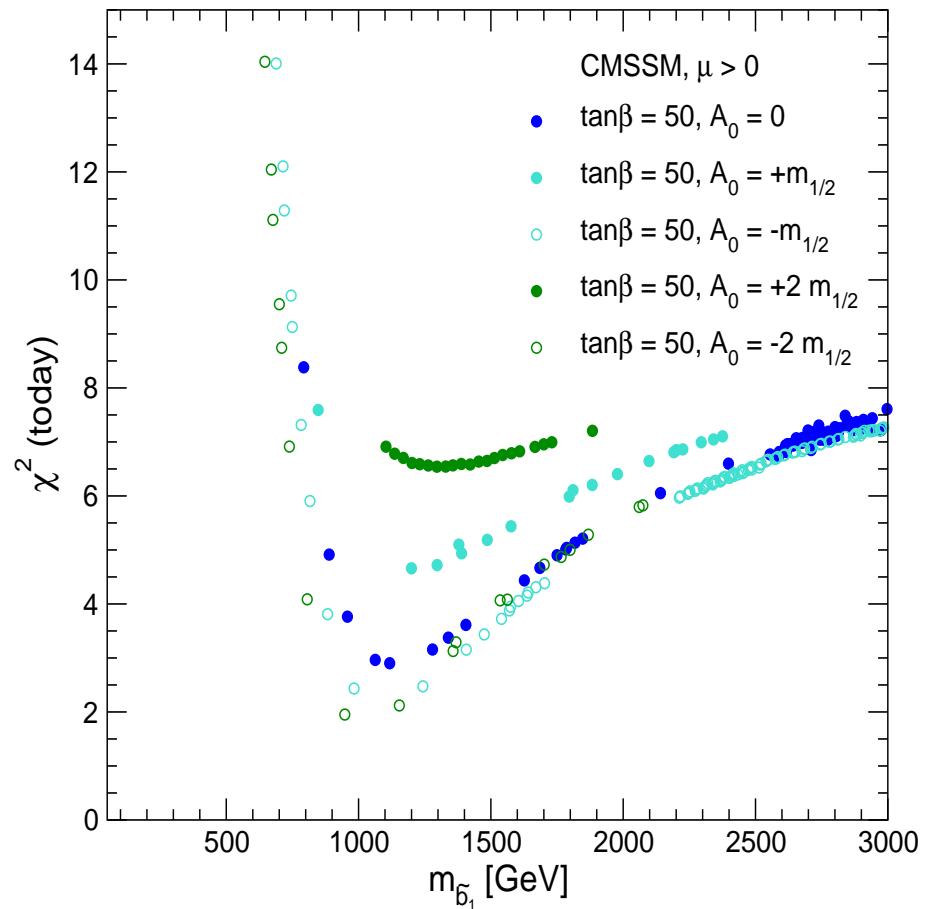
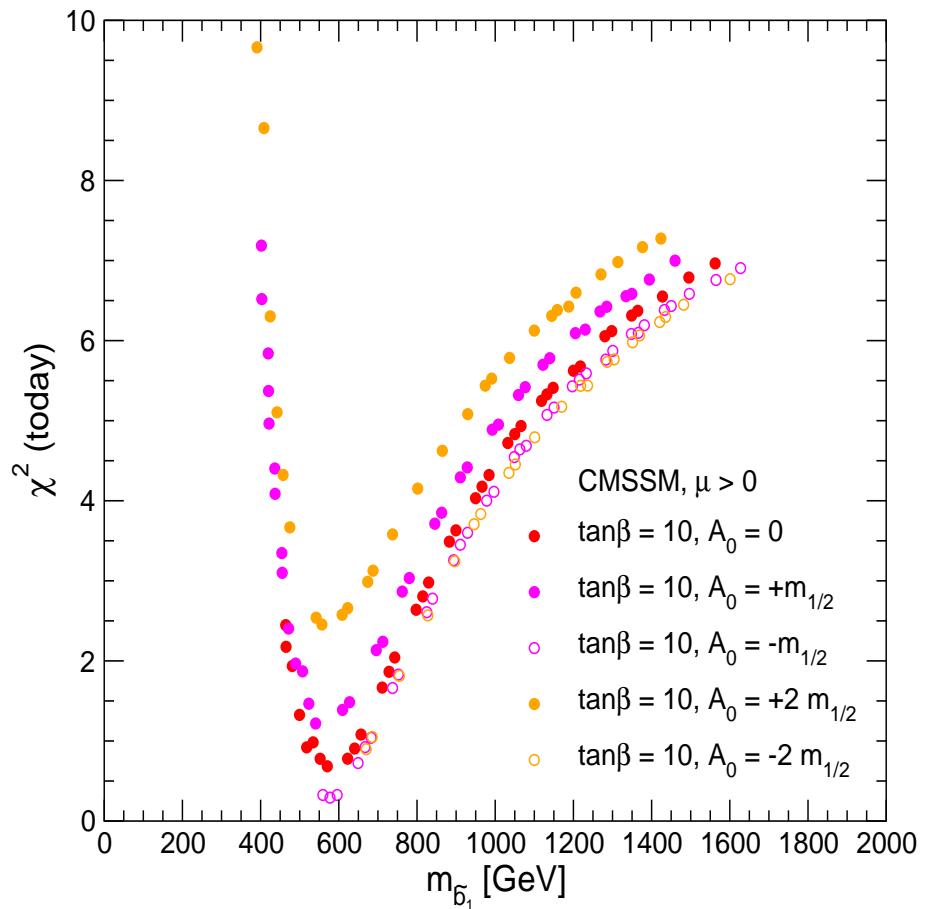
lightest stop mass for $\tan\beta = 10, 50$



$\tan\beta = 10 \Rightarrow$ very good prospects for the LHC, not too good for the ILC

$\tan\beta = 50 \Rightarrow$ still quite good for the LHC

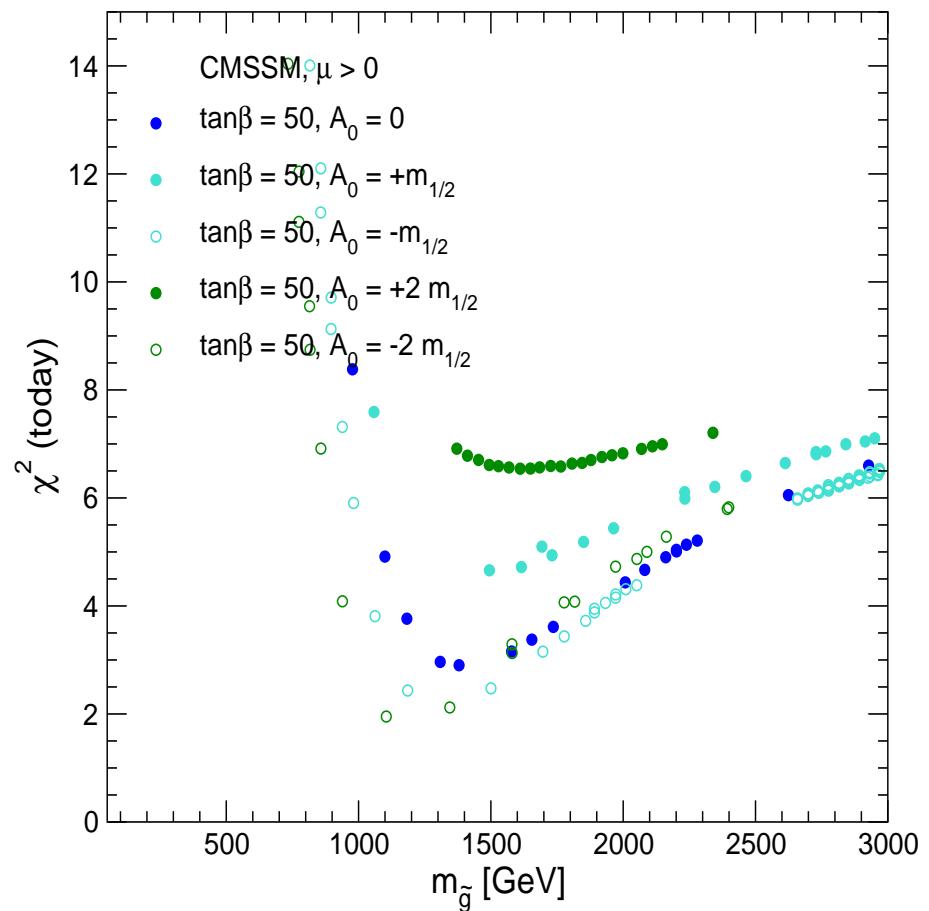
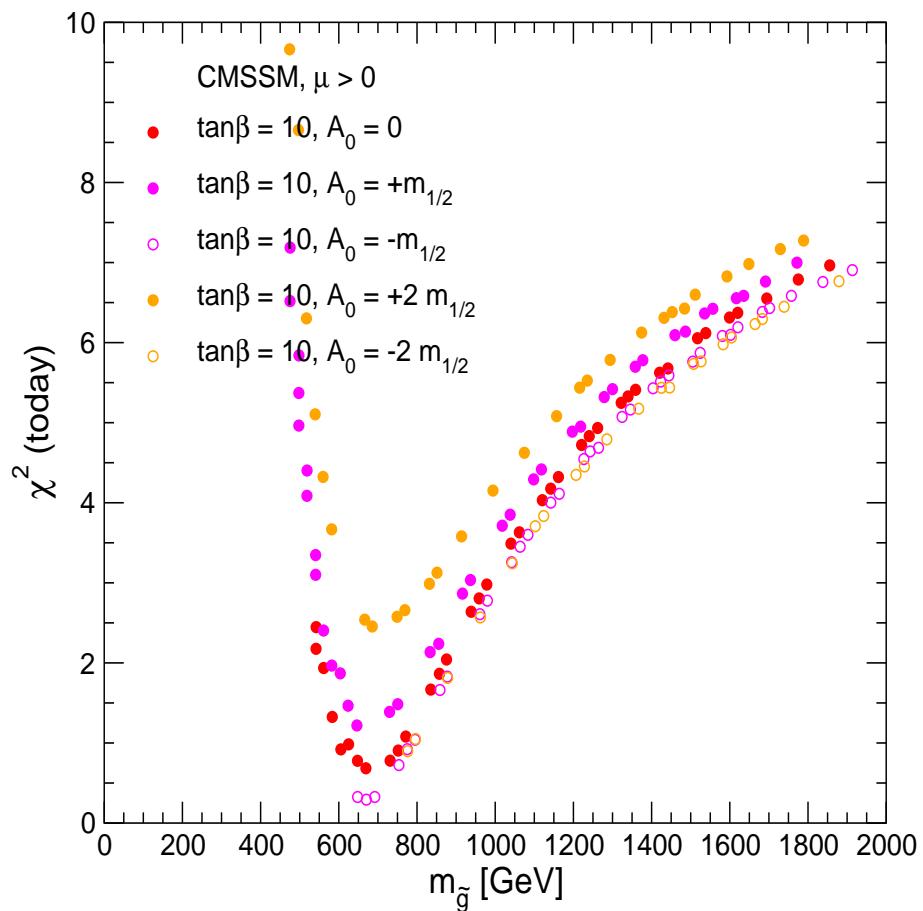
lightest sbottom mass for $\tan\beta = 10, 50$



$\tan\beta = 10 \Rightarrow$ very good prospects for the LHC, not too good for the ILC

$\tan\beta = 50 \Rightarrow$ still quite good for the LHC

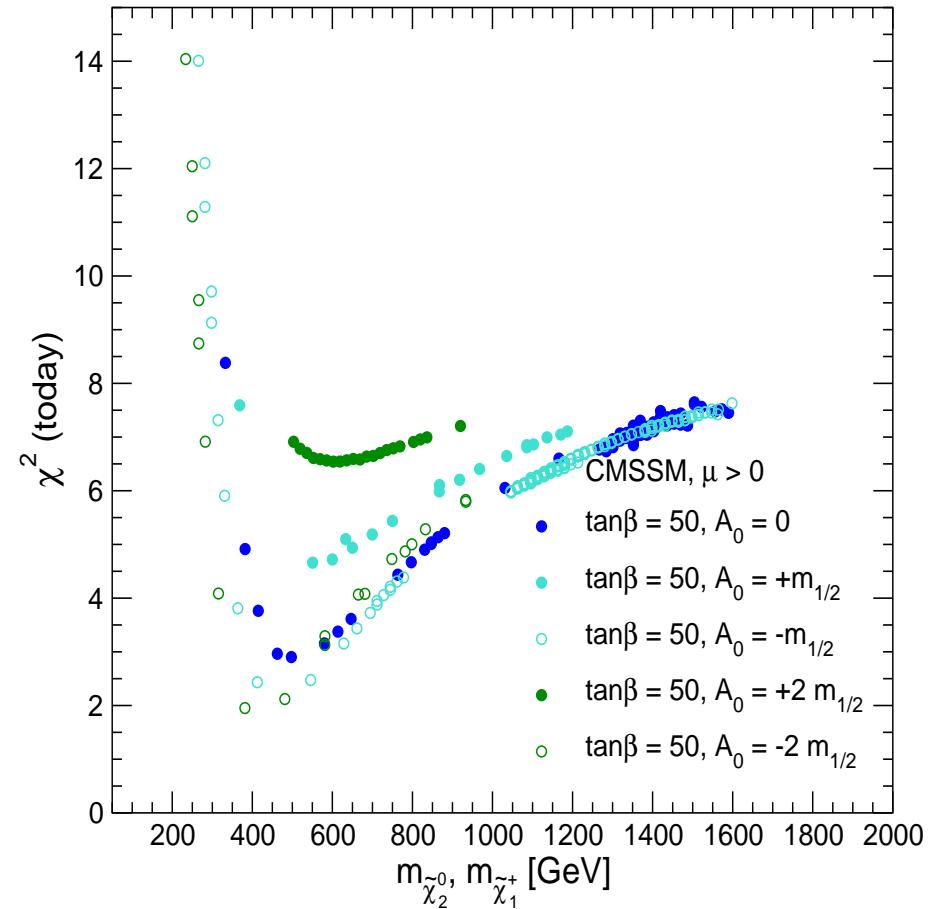
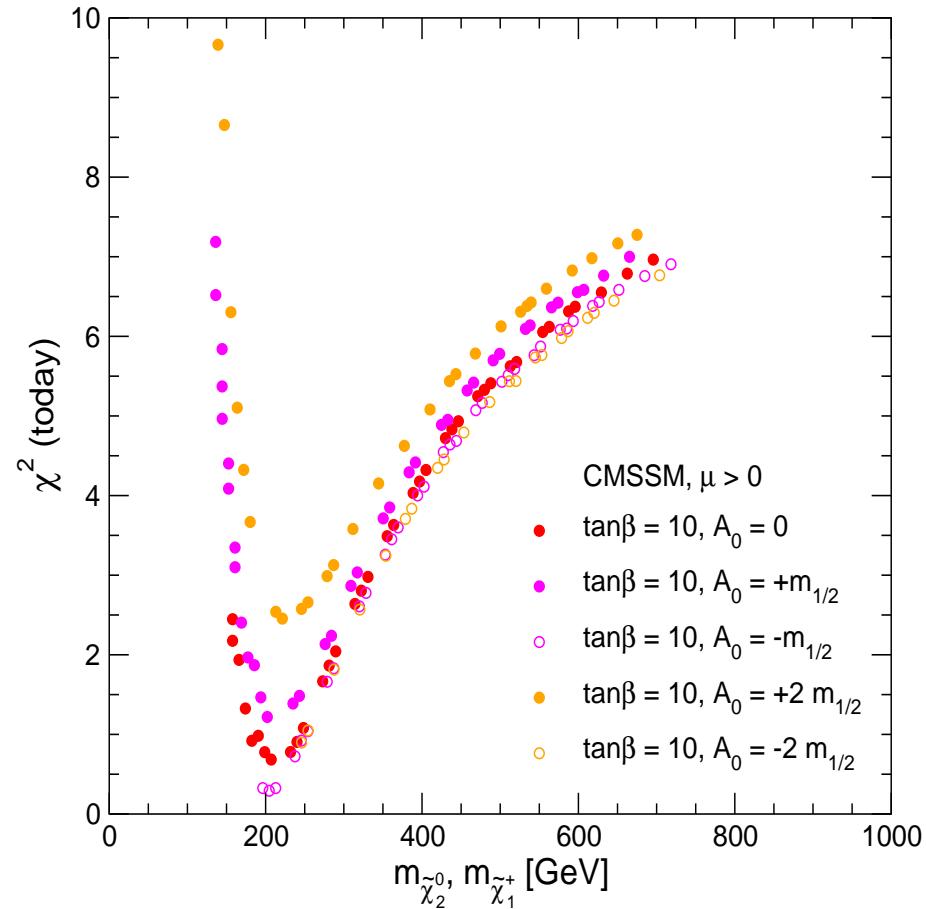
gluino mass for $\tan\beta = 10, 50$



$\tan\beta = 10 \Rightarrow$ very good prospects for the LHC, hopeless for the ILC

$\tan\beta = 50 \Rightarrow$ still quite good for the LHC

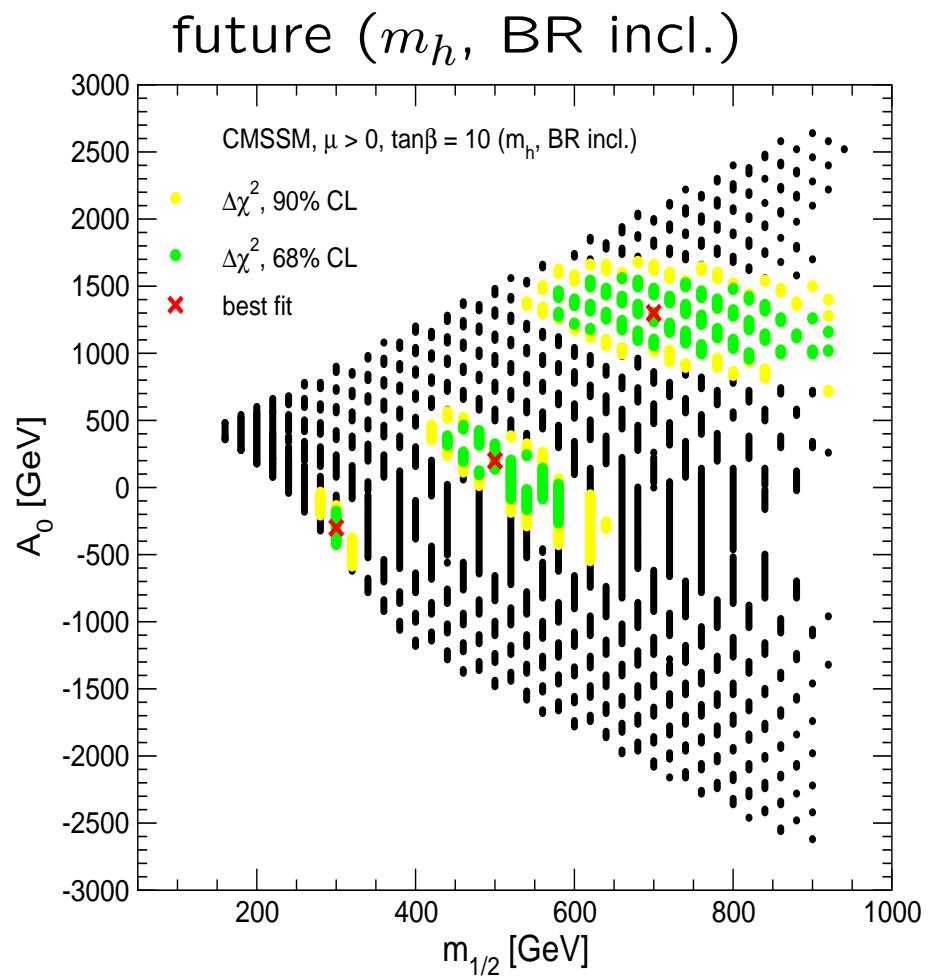
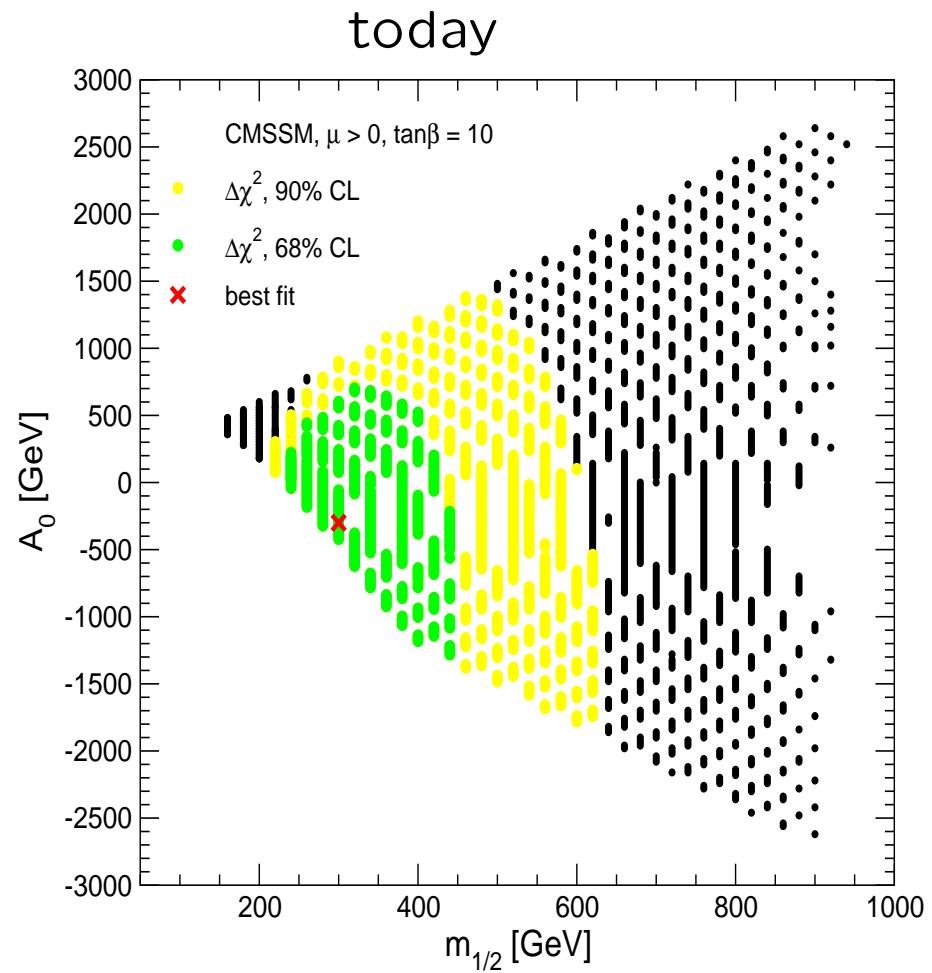
lightest chargino/next-to-lightest neutralino mass for $\tan\beta = 10, 50$



$\tan\beta = 10 \Rightarrow$ very good prospects for both, LHC and ILC

$\tan\beta = 50 \Rightarrow$ still quite good

Compare current and future fit:



Future reach of precision observables larger than direct collider reach

4. Conclusions

- Precision observables
 - can give valuable information about the “true” Lagrangian
 - can provide bounds on SUSY parameter space
- Most important electroweak precision observables:
 M_W , $\sin^2 \theta_{\text{eff}}$, m_h , $(g - 2)_\mu$, b physics
- Three types of errors:
experimental: sets the scale
intrinsic: unknown higher-order corrections (what we are working on)
parametric: exp. error on input parameters (experimentalists work)
- Current χ^2 fit: indication for not too large SUSY masses
 - ⇒ good prospects for the LHC and the ILC
 - ⇒ future indirect reach larger than kinematical collider limit

Experimental situation:

Current/future Experiments

→ provide high accuracy measurements !

Theory situation:

measured observables have to be compared with theoretical predictions
(of your favorite model)

Measured data is only meaningful if it is matched with theoretical calculations at the same level of accuracy

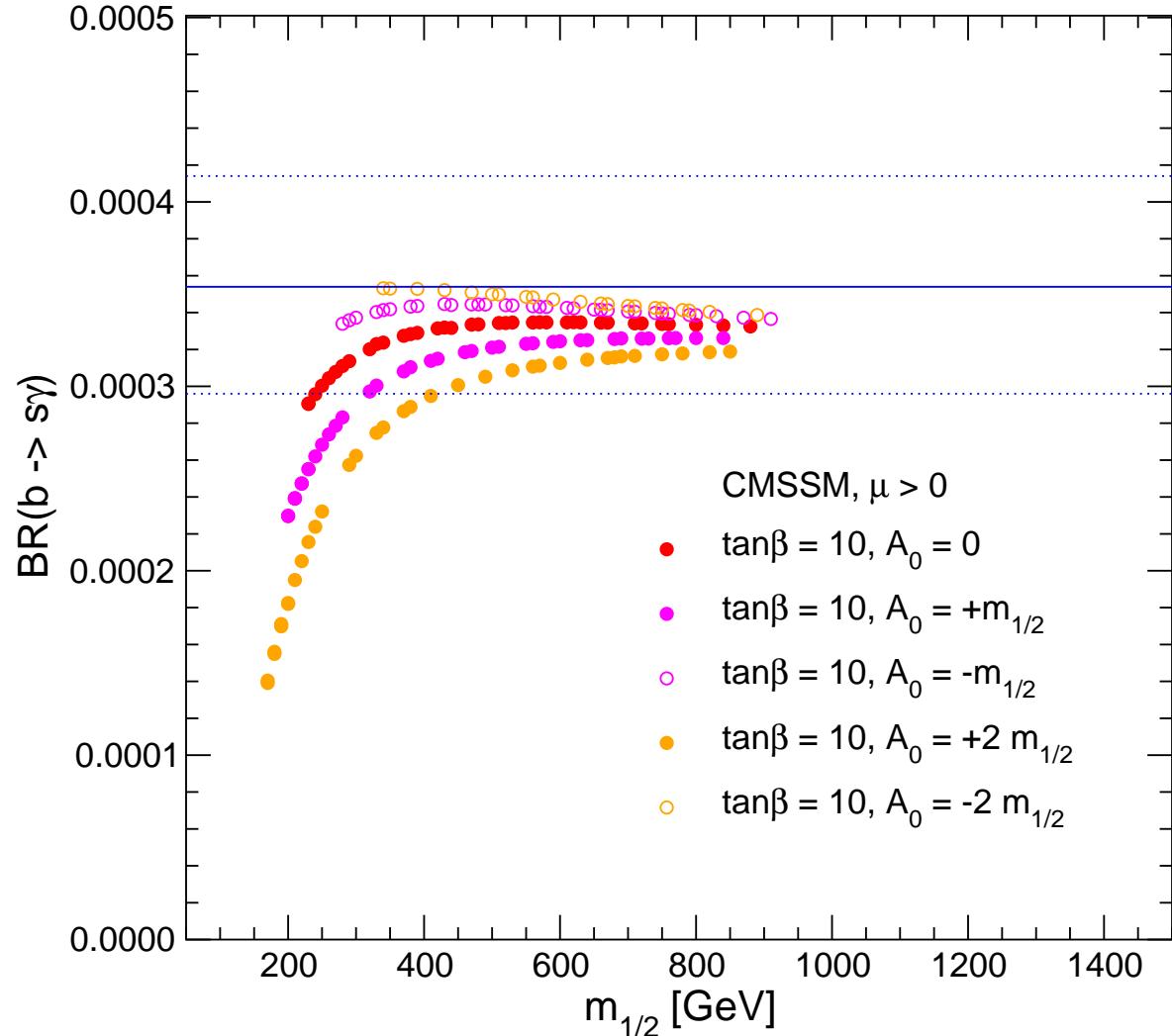
We have to start **NOW** to achieve necessary accuracy in time

Theoretical calculations should be viewed as an essential part of all future High Energy Physics programs

Backup slides

Investigation of mSUGRA with cold dark matter constraint:

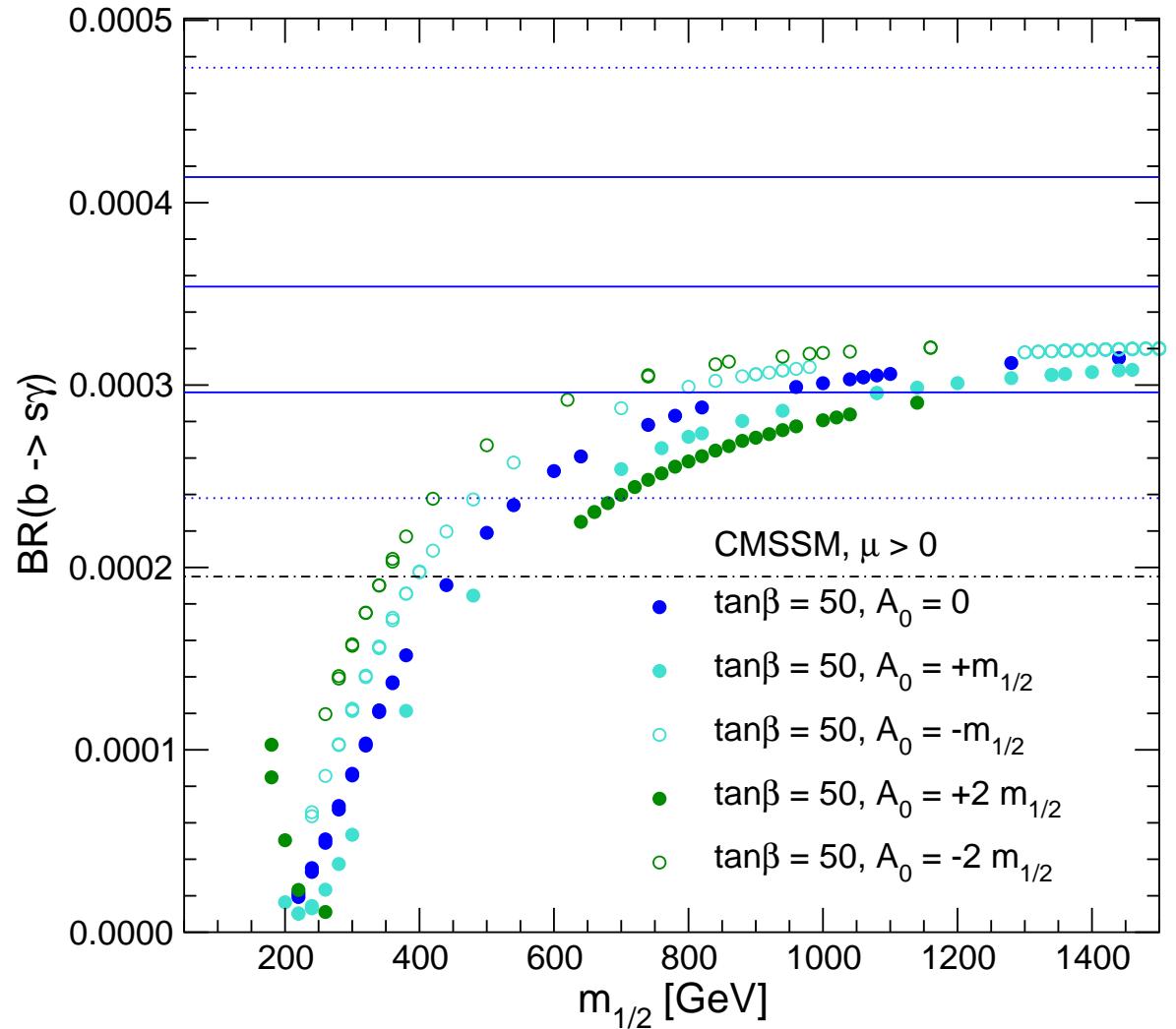
$\text{BR}(b \rightarrow s\gamma)$, $\tan\beta = 10$



Scan over $m_{1/2}, m_0, A_0$
 $\tan\beta = 10$
selected points give correct
amount of cold dark matter
[Ellis, S.H., Olive, Weiglein '04]

Investigation of mSUGRA with cold dark matter constraint:

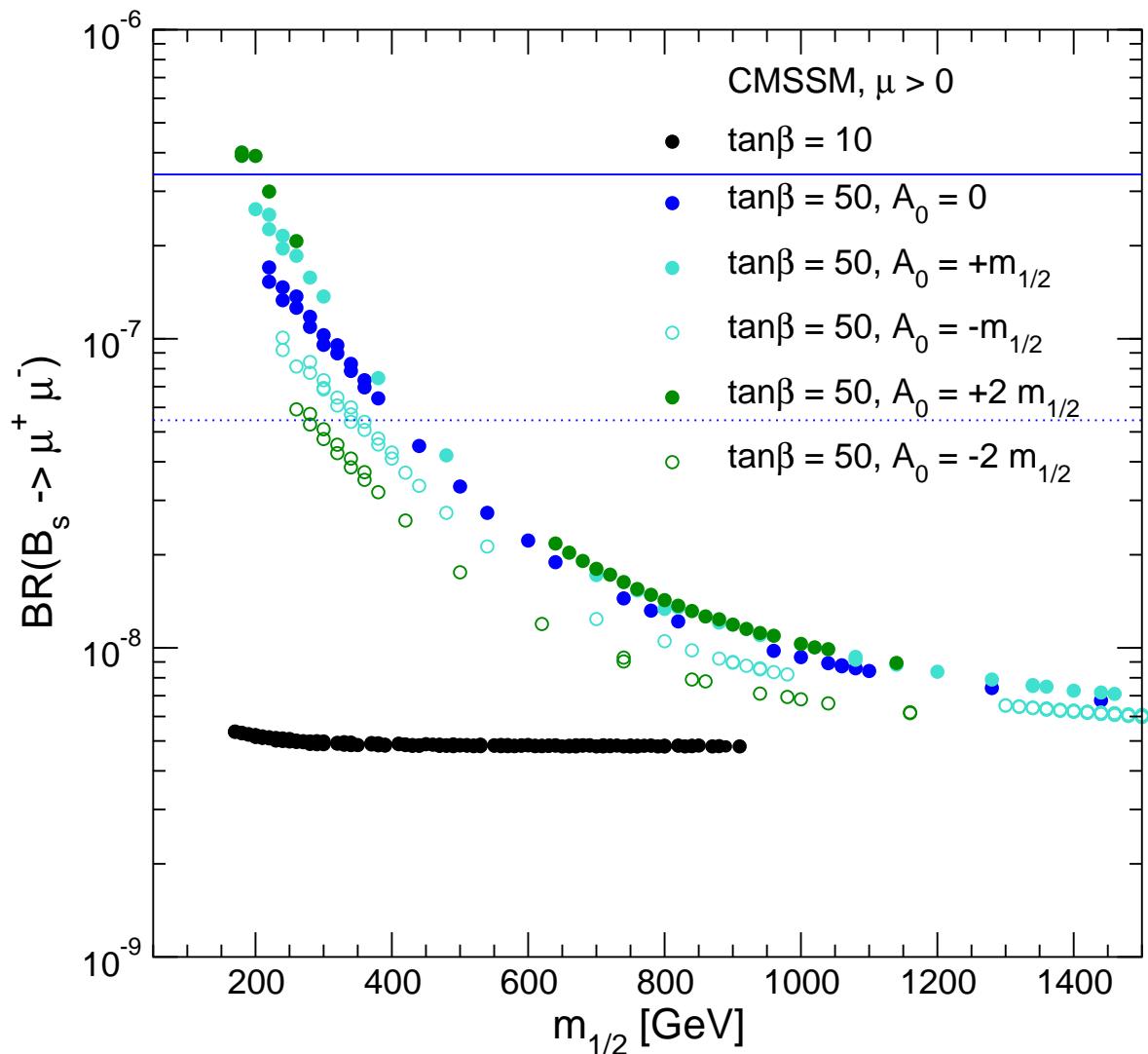
$\text{BR}(b \rightarrow s\gamma)$, $\tan\beta = 50$



Scan over $m_{1/2}, m_0, A_0$
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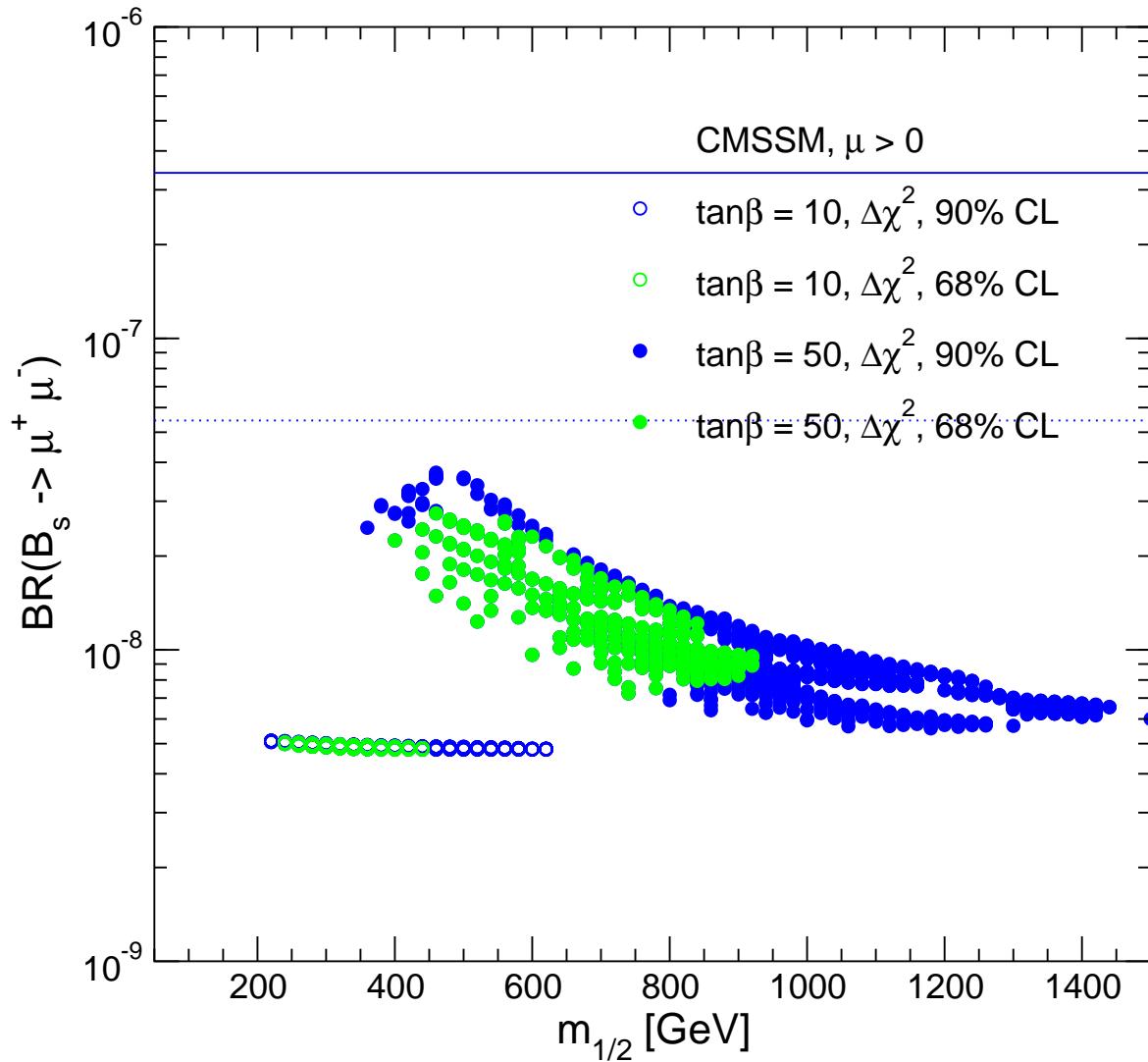
$\text{BR}(B_s \rightarrow \mu^+ \mu^-)$



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